Early childhood multidimensional development

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A RAPID AND NON-LINEAR ROLLER COASTER

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Early childhood multidimensional development

A rapid and non-linear roller coaster

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CONTENTS

Chapter 1

GENERAL INTRODUCTION

1.1 Introduction

The early childhood years constitute a period of rapid learning and development of children's motor, cognitive and social skills (United Nations Educational, Scientific and Cultural Organization, 2014). The development of these years is critically important as it provides the foundation for health and wellbeing throughout life and strongly predicts later school enrolment and life success (ISSA, 2016; Yoshikawa et al., 2007). The period of early childhood can range from birth to the age of 8 (UNESCO, 2014). In this study, we focus on the period of early childhood that spans from ages 3 to 6, as this is the period when children attend early childhood education centers in many school systems, including Mexico, where this study is situated.

In the early childhood years, children develop at an accelerated pace and show a non-linear development (Malina, 2013; Meisels, 2007; Petersen, Hoyniak, McQuillan, Bates, & Staples, 2016; Shepard, Kagan, & Wurtz, 1998). This period is marked by a dramatic brain and cognitive development, as it is when the brain has a high capacity of change and it is highly responsive to the inputs of the environment (ISSA, 2016; UNESCO, 2014; Zelazo, Qu, & Kesek, 2010). Furthermore, children of this age range show an accelerated physical and motor development and are in the developmentally appropriate moment to learn social skills (Denham et al., 2013; Kuther, 2016). Beyond these general developmental trends, there is considerable variability among children, as each child develops at their own pace, which might not follow a linear growth and differ on each developmental domain (Bornstein, 2013; Malina, 2013; Shepard, Kagan, & Wurtz, 1998).

Early childhood is also the period that children prepare for the initiation of formal schooling. To be ready for school, children must have the basic minimum skills and knowledge in a variety of domains that give them the tools to be successful in school (United Nations Children's Fund, 2012). Early childhood education aids not only to boost children's cognitive and language skills but also promotes their physical health and well-being and their socioemotional skills (UNESCO, 2006). In this sense, 'school readiness' is not limited to a specific area of development; on the contrary, it embraces an integrative perspective on child development by exploiting the interrelations between and across domains (UNICEF, 2012).

In the past decades, there has been increasing recognition of the need to adopt a holistic view on early childhood development and, consequently, on the assessment of children in a variety of areas (Bronstein, 2013). Experts on early childhood agree on five key domains of early childhood development: (1) physical wellbeing and motor development, (2) socioemotional development, (3) approaches to learning, (4) language and early literacy, and (5) cognitive functioning (National Education Goals Panel, 1997; Snow & van Hemel, 2008). Furthermore, the holistic, dynamic and intertwined development of children on these domains creates a developmental synergy, in which the progress or lack of progress in one of the developmental domains may enhance or abate the development of other developmental domains (Snow, 2007; UNESCO, 2014). Therefore it is vital that these domains are considered and investigated in combination and not as separated entities (Snow & van Hemel, 2008; UNESCO, 2014). Accordingly, the present research project set out to study the development of young children in a multidimensional manner, by exploring the development and interactions of different skills in key developmental domains: pre-academic skills, motor skills, executive functions, and socio-emotional competence.

Pre-academic skills. Early literacy and early numeracy are basic interrelated skills that are fundamental for reading, writing, and mathematical achievement. Through early literacy, children acquire the basic attitudes, knowledge, and skills—coding and oral—that are required for reading and writing (Storch & Loningan, 2002; Whitehurst & Lonigan, 1998). Through early numeracy, children develop the preparatory skills for mathematical achievement: numbering, numerical relations and arithmetic operations (Purpura, Hume, Sims, & Lonigan, 2011; Raghubar & Barnes, 2017).

Motor skills. The fundamental motor skills—including locomotor, manipulative, and balance skills—are the foundation for more sophisticated and distinct motor skills (Logan et al., 2018; Malina, 2003). A classical distinction is between gross and fine motor skills. Gross motor skills involve the use of large muscles and comprise balance, orientation, and the movement of trunk and limbs. Fine motor skills involve the coordination of small muscles to achieve motor precision and integration (Cameron, Cottone, Murrah, & Grissmer, 2016; Van der Fels et al., 2015).

Executive functions. These are high order cognitive processes that guide the control of thought and action (Carlson, 2005). In young children, there are two basic distinguishable but interrelated subdomains: inhibitory control and working memory (Lerner & Lonigan, 2014; Miller et al., 2012; Karalunas, Bierman, & Huang-Pollock, 2016). Inhibitory control refers to the ability to suppress predominant responses in order to give an alternative response, and working memory refers to the ability to update and monitor mental information (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). An additional distinction has been made between cool and hot executive functions. Hot executive functions involve affective and motivational processing and demand constant evaluations of the affective self-significance of the stimuli. In contrast, cool executive functions are evoked by abstract decontextualized problems (Zelazo & Müller, 2002).

Socioemotional competence. This refers to a set of social and emotional skills that are inextricably interrelated. These skills include—but are not limited to—the capability to develop positive relations with others, the ability to communicate feelings and coordinate actions with a social partner, and to identify, regulate and express emotions in a cultural and socially appropriate manner (Campbell et al., 2016; Camras, Shuster, & Fraumeni, 2014).

1.2 Contextual issues that guided the motivation for the project

Mexico was one of the first country in which attendance to Early Childhood Education (ECE) became obligatory for every child from 3 to 5 years and 11 months. As of 2002, children are expected to complete three years of ECE: ECE 1 (from 3 to 4 years old), ECE 2 (from 4 to 5 years old) and ECE 3 (from 5 to 6 years old; Diario Oficial de la Federación, 2002). This change in the educational law represented a challenge not only logistically, but also required that the curriculum was adapted and extended to cover 3- year-old children.

Public preschools are under the responsibility of the government and provide—on a free basis—the highest coverage of ECE in the country (83.6% public vs 16.4% private; INEE, 2018). By 2012 almost 85% of the children from 3 to 6 years old were enrolled in an ECE center. However, despite considerable efforts of the government to provide a complete coverage of basic education, Mexican students perform consistently low in academic achievement on international comparative assessments like PISA (i.e., students underperform in sciences, reading and mathematics; OCDE, 2016). Moreover, there is an alarming upward national trend of child overweight. Mexico has the highest prevalence of child overweight worldwide. This trend has been related not only to nutritional factors but also to a lack of physical activity (Turnbull, Gordon, Martínez-Andrade, & González-Unzaga, 2019; WHO, 2017). Student underperformance in PISA and the increase in child overweight have pushed researchers, policymakers and governmental entities to search for alternatives to counteract both trends. A possible approach to address both trends simultaneously may be to expand the typical narrow focus on the promotion of children's academic achievement. A study that explores multiple domains of child development—such as academic achievement, but also motor skills and other domains—and the interrelations among them, might shed light on novel and more effective ways to reverse these trends.

1.3 Overall research project

The general aim of the project entitled Estudio del Desarrollo Integral del Preescolar - EDIP (Study of the Integral Development of Preschool children) was to explore the development and relations between multiple developmental domains in Mexican young children—3 to 6 years of age. For doing so, a longitudinal assessment of 279 young Mexican children was conducted.

The general setup of the longitudinal design in this project—an accelerated longitudinal design—is presented in Table 1.1. An accelerated longitudinal design utilizes a strategy of planned missing data, in which the longitudinal information gathered on different cohorts is reordered to optimize the information and cover the full age span available in the whole sample (Little, 2013). In this case, the empty cells due to the reordering of data are estimated using modern techniques for missing data handling. For such estimation, the information of the overlapping period serves to accurately project the associations among all variables at hand (Little, 2013). In our project two cohorts of children were assessed in four measurement occasions, and then, the information was merged and reordered into the six time points of an accelerated design (as shown in Table 1.1) to cover the three years of ECE. The two assessments conducted at ECE2 were the overlapping points across cohorts and multiple imputation was used to treat the missing data.

1.4 Research rationale

Given the accelerated, non-linear and multidimensional development of young children, research on child development faces a set of diverse challenges. One of them, is the main assumption that measures are invariant. Measurement invariance refers to the statistical property that a construct is measured in an equivalent manner across groups or measurement occasions (Meredith & Horn, 2001) which is vital to make a fare and clear comparison among them. Although the very nature of child development and its non-linear growth challenges this assumption, it is a common practice in social sciences research to assume invariance without

Table 1.1 *Transformation of the longitudinal data collection into the accelerated longitudinal design*

Original format of longitudinal data collection						
	M1	M2	M3	M4		
Cohort 1 *n* (ECE1)	127	127	98	103		
Cohort 2 *n* (ECE 2)	139	140	115	121		
Cohort 3[a] *n* (ECE 3)	105	x	x	x		
Accelerated longitudinal design						
	ECE 1 Halfway[b] (T1)	ECE 1 End[c] (T2)	ECE 2 Halfway[b] (T3)	ECE 2 End[c] (T4)	ECE 3 Halfway[b] (T5)	ECE 3 End[c] (T6)
Cohort 1 'Younger cohort'	M1	M2	M3	M4	*	*
Cohort 2 'Older cohort'	*	*	M1	M2	M3	M4

Note. M = measurement occasion, T = time point, x = not assessed, * = Imputed data missing by design. ECE = early childhood education. [a] Cohort 3 was only assessed in the first measurement occasion, therefore was not included in the accelerated design. [b] Assessed halfway of the school year (January). [c] Assessed at the end of the school year (June-July).

empirically testing it. In this project, we explore the stability and equivalence of latent constructs representing key developmental domains. Additionally, we open the debate about the tension that exists between the methodological necessity of having invariant constructs and the inherent rapid and non-linear development in early childhood.

Furthermore, to expand the multidimensional view of child development and school readiness it is necessary to focus not only on the isolated domains but most importantly to understand the interconnections between developmental domains (Snow, 2007; UNICEF, 2012). In our project, executive functions play a central role, as they are considered an anchor that connects with and influences different developmental domains. This happens, on the one hand, by acting as a mediator in the relation between motor and pre-academic skills, and, on the other hand, by having a bidirectional relation with socioemotional competence.

Regarding the relation between executive functions and socioemotional competence, it is widely recognized that executive functions contribute to the development of self-control, emotion regulation, prosocial behavior and social competence (Carlson & Wang, 2007; Huyder & Nilsen, 2012; Katzir, Eyal, Meiran, & Kessler, 2010; Rhoades, Greenberg, & Domitrovich, 2009). Recent studies, however, propose that emotions and social interactions provide also an important input for the development of executive functions (Ferrier, Bassett, & Denham, 2014; Hala, Pexman, Climie, Rostad, & Glenwright, 2010). Nonetheless, empirical research that explores the bidirectional association between executive functions and socioemotional competence is still incipient. In addition, the traditional way of assessing socioemotional competence—restricted mainly to parent and teacher reports—has limited our understanding about direct child expressions of socioemotional competence.

Moreover, it has been proposed that executive functions may be the cognitive process that explains the relation between motor skills and pre-academic skills (Roebers et al., 2014). There is ample evidence on the connection between motor skills and executive functions (e.g. Ahnert, Schneider & Bos, 2009; Davis, Pitchford, & Limback, 2011; Livesey, Keen, Rouse, & White, 2006; Roebers et al., 2014), and between executive functions and pre-academic skills (e.g. Lonigan, Lerner, Goodrich, Farrington, & Allan, 2016; Purpura, Schmit, & Ganley, 2017). However, there is no consensus yet about the nature and magnitude of the relation between motor and pre-academic skills in young children. Although theoretically executive functions have been placed as a central pivotal point in the relation between motor skills and pre-academic skills, further empirical exploration is needed to clear up the possible mediator role of executive functions in young children.

Collectively, our project aimed to enlighten the relational paths between executive functions and socioemotional competence, and between executive functions and motor and pre-academic skills as a first step to generate a developmental synergy that help better promote child development. In light of the current situation in Mexico it seems vital to explore alternative ways to stimulate development from a young age. Finally, obtaining a better understanding of the interconnections and multidimensional development of young children, will help to foster strategies that promote not only the cognitive and academic development, but also highlighting the relevance of the development of motor skills and socioemotional competence.

1

1.5 The dissertation

The present dissertation includes three empirical studies. Figure 1.1 provides an overview of the data collected as part of the longitudinal design, as well as which information were included in the analyses reported in the empirical chapters.

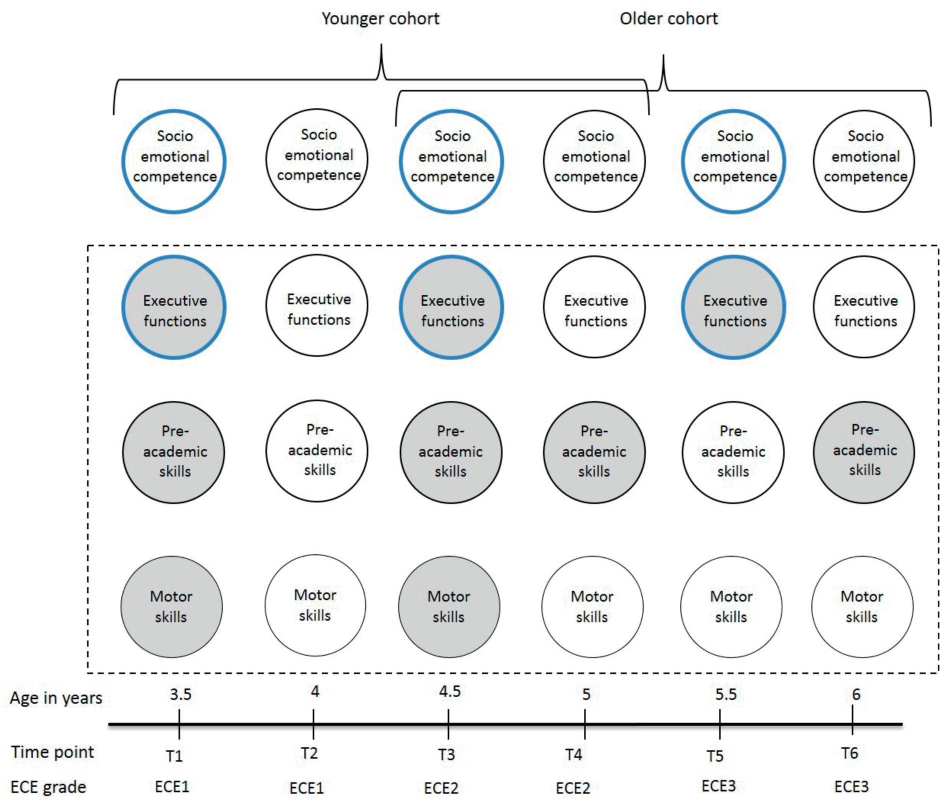

Figure 1.1. Project overview. At the top of the figure, two braces demarcate the variables that were assessed at each measurement occasion per cohort. At the bottom, a time line presents the equivalences between age, time points and grades of early childhood education (ECE). Variables inside the dotted square were used in Chapter 2. Variables shaded light gray were used in Chapter 3. Variables marked with a bold blue border were used in Chapter 4.

Chapter 2 derived from the methodological necessity to define the structure for each domain that would adequately replicate across different age groups involved in the study. Conscious of the accelerated and non-linear development of young children, this study intended to enlighten the tension that exists between the methodological necessity of having invariant constructs—as this is a basic assumption of most longitudinal statistical analyses—and the rapid and non-linear development in early childhood. Therefore, Chapter 2 was devoted to explore the stability and equivalence of the latent constructs representing pre-academic skills, executive functions and motor skills. We explored whether pre-academic skills were best represented by a single factor model or by a two distinctive but related factors—early numeracy and early literacy. For executive functions, we also explored two factor structures, a single factor model and a model with two distinctive but related factors—inhibitory control and working memory. Finally, for motor skills three different factor structures were explored, a single factor model, a model with two distinctive but related factors—fine and gross motor skills, and a three-factor model—manual dexterity, aiming and catching, and balance. Furthermore, we explored whether the same structure held for different measurement occasions and in different early childhood education grades, by addressing the issue of measurement invariance in a longitudinal and a cross-sectional design.

Chapters 3 and 4 explore the multidimensional and intertwined development of the selected domains within the early childhood period. In Chapter 3, we explored the relation between motor skills and pre-academic skills, and we examined the role of executive functions as a possible mediator in this relation. Based on the strong theoretical and empirical evidence on the relations between executive functions and motor skills, and between executive functions and pre-academic skills, we placed executive functions as a mediator between motor skills and pre-academic skills. We tested a mediation model with the aforementioned domains in two separate cohorts, a younger cohort—including children from 3.5 to 5 years old, and an older cohort—including children from 4.5 to 6 years old. In Chapter 4, we explored the possible bidirectional relation between executive functions and socioemotional competence. For this chapter, we adopted a person-centered approach to depict the development of socioemotional competence of young children throughout the early childhood education period. We generated socioemotional profiles based on the children's responses to hypothetical challenging social situations at three time points—at 3.5, 4.5 and 5.5 years old—and explored how children transition among the different profiles. Furthermore, by means of an associative latent transition analysis, we explored the bidirectional relation between socioemotional competence and executive functions (hot and cool components).

Finally, in Chapter 5 we present a recapitulation of the main findings of this dissertation. Moreover, we discuss the key findings and limitations of our project as well as general recommendations and implications for practice and future research.

Chapter 2

THE RAPID, NON-LINEAR AND MULTIDIMENSIONAL DEVELOPMENT IN EARLY CHILDHOOD: CHALLENGES FOR ACHIEVING MEASUREMENT INVARIANCE

The rapid, non-linear and multidimensional development in early childhood: Challenges for achieving measurement invariance

Abstract

The rapid and non-linear development in early childhood represents a challenge for assessing development. Therefore, this study explored the structure and stability of three domains—pre-academic skills, executive functions, and motor skills— in children aged 3 to 6 years old, using a cross-sectional (*n* = 371) and a longitudinal design (n = 279). In general, pre-academic skills and executive functions were better characterized by a single factor structure and motor skills by a two-factor model. Partial configural and metric invariance was achieved for all domains; however, none of the domains showed scalar invariance in either design. A discussion is opened about the tension between the analytical assumption of invariance and the changing nature of development in the early childhood period.

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2.1 Introduction

Developmental research aims to understand, estimate and capture the specific characteristics of growth processes (Grimm, Ram, & Hamagami, 2011). One of the main challenges of applied developmental researchers is to appropriately capture development with—always limited—assessment methods (Snow & van Hemel, 2008). This is particularly problematic in the early childhood years, a time period where the very nature of children's rapid and non-linear development, challenges our assessment methods and assumptions (Meisels, 2007; Shepard, Kagan, & Wurtz, 1998). One of the main assumptions in applied research is that measures are *invariant*. Measurement invariance refers to the statistical property that a construct is measured in an equivalent manner across groups or measurement occasions (Meredith & Horn, 2001). Although unjustified, assuming invariance is a common practice in social sciences research (Gregorich, 2016; Kern, McBride, Laxman, Dyer, Santos, & Jeans, 2016).

In this study we aimed: (1) to explore the stability and equality of three developmental domains—pre-academic skills, executive functions and motor skills—by means of testing measurement invariance, and in this way, contribute to their operationalization; and (2) to determine the level of measurement invariance—configural, metric or scalar—for a cross-sectional and a longitudinal design; and by doing this, to open a debate about the limitations of the current research practices and techniques in developmental research and their assumptions. In the next section, we present first evidence on the developmental characteristics of young children and the challenges inherent in their assessment. Afterwards, we provide an overview of the measurement invariance construct and its operationalization. Finally, we present three developmental domains—pre-academic skills, executive functions, and motor skills—as examples for assessing measurement invariance in young children.

2.1.1 Early childhood rapid and non-linear development

Children in the early childhood years are characterized by a rapid growth rate and a non-linear development. The rapid growth in this period is marked by a dramatic brain and cognitive development, and an accelerated physical and motor development (Kuther, 2016). The non-linear nature of child development—also referred as instable, disharmonic, heterotypic, discontinuous, and asymmetric— is observed at domain level as well as at the child level (Malina, 2013, Meisels, 2007; Petersen, Hoyniak, McQuillan, Bates, & Staples, 2016; Shepard, Kagan, & Wurtz, 1998). At the domain level, for example, executive functions seem to have an important development acceleration between 3 and 4 years old, which accounts for 60% of the total change of the latent executive functions in early childhood (Willoughby, Wirth, & Blair, 2012). Another example is on the development of motor skills, which has been described as asymmetric, as it can shift between long periods of stability and sudden bursts of progress, or even a regression to previous stages before moving to more advanced stages (Malina, 2013). Furthermore, the development of young children has also been described as heterotypic, a characteristic that reflects that a construct and its underlying process have different behavioral manifestations at different developmental periods (Cicchetti & Rogosch, 2002). Overlooking the heterotypic nature of a developing domain is problematic for research. If the manifestations of a certain domain change depending on the developmental moment, then the scores of the measures utilized across time occasions may reflect the differences on the representation of the construct and not per se a change in the development of the domain (Petersen et al., 2016).

At the child level, it has been shown that young children present a high developmental variability, due to their idiosyncratic developmental pace, which might not follow a linear growth (Bornstein, 2013; Shepard, Kagan, & Wurtz, 1998). For example, Malina (2013) illustrates the disharmonic development of motor skills in young children by arguing that a child might be at an immature stage in one skill and at a more advanced stage in another skill, and that this fluctuates at different moments in time. Lastly, the development of motor skills seems to be continuous when children are grouped together and data are aggregated as average trends, but this representation does not accurately reflect the variability among children (Malina, 2013).

2.1.2 Challenges in the assessment of young children

The assessment of young children represents specific challenges for a variety of interconnected reasons. Firstly, young children are, as expressed by Meisels (2007, p. 35), “developmentally unreliable test takers”. Several characteristics of the assessment situation may be particularly challenging for young children, such as their limited attention span, their restricted ability to comprehend complex verbal or written instructions, and their susceptibility to fatigue or boredom (Meisels, 2007). Secondly, since early childhood is characterized by accelerated development, this also complicates the selection of measures that are developmentally sensitive and appropriate for the entire age span of interest (Petersen et al., 2016). A developmentally appropriate measure is adequate to the capacity of the children in a particular developmental level, whereas a developmentally sensitive measure has enough variability across children in the same condition, for example, within the same age range (Petersen, et al., 2016). Thirdly, developmental domains are highly intertwined in early childhood, which complicates the assessment and the interpretation of one domain without the influence of other domains (Snow & van Hemel, 2008). Finally, based on the non-linear nature of the development of young children, there is a simultaneous demand of greater consideration of the conceptualization and operationalization of the constructs at different developmental states (Knight & Zerr, 2010). This final measurement issue can be investigated by testing the measurement invariance—also described as measurement equivalence or factorial invariance, which will be thoroughly explained in the next section.

Apart from the nature and appropriateness of measurement instruments, the research design is also an important factor in the study of child development. Two designs are commonly used to study the development of young children: cross-sectional and longitudinal. Many studies in early childhood are based on a cross-sectional design, in which, for example, children of a certain age-range are assessed to explore differences in performance when compared to children from a different age-range (Meredith & Horn, 2001; Willoughby, Wirth, & Blair, 2012). In contrast, longitudinal designs aim to explore the stability or instability of a specific domain in the overall course of a child's development (Bornstein, 2013). Whether development is studied through longitudinal or cross-sectional designs, researchers must be certain that differences over time or across age groups stem from the phenomenon of interest, and not from changes in measurement or the psychometric properties of the scale used (Putnick & Bornstein, 2016; Petersen et al., 2016). Most importantly, the accuracy of the research results will depend on the equivalence of the measures—by age or demographic group—as differences on the measures may inflate or obscure the nature of the results (Kern et al., 2016; Knight & Zerr, 2010).

2.1.3 Measurement invariance

Measurement invariance refers to the statistical property that provides objective evidence that the manifest indicators that are assumed to measure a given latent construct do indeed measure that latent construct in the same way for different groups or at different measurement occasions (Meredith & Horn, 2001). Measurement invariance is a prerequisite in the modeling of latent constructs, that is, constructs that are not directly observed (e.g., pre-academic skills) but are represented by a series of manifest indicators (e.g., vocabulary, numbering, and identification of letters and words) that are directly observed (e.g., by tests or questionnaires; Gregorich, 2016). Measurement invariance evaluates whether the latent construct of interest is represented by the manifest indicators in an equivalent manner among groups and across time (Putnick & Bornstein, 2016; Petersen et al., 2016). There are two approaches to measurement invariance: multi-group invariance and longitudinal invariance. The first explores the equivalence of a latent construct on a between-subject level for two or more groups (e.g., cohorts), and is based on single-point estimates—for example, cross-cultural, gender or age comparisons. The latter explores the equivalence of constructs on a within-subject level (e.g., multiple measurement occasions) and focuses on development over time (Gregorich, 2006; Meredith & Horn, 2001).

In the present study, we focus on three basic levels of invariance: configural, metric and scalar invariance. Configural invariance refers to the basic organization of the latent constructs—their factorial structure (also referred to as the base-line model)—and it is attained when the same number of manifest indicators is present across groups or measurement occasions, and they load on the same latent construct (Gregorich 2006, Putnick & Bornstein, 2016). This level of invariance is qualitative, as it assesses the general structure of the latent construct. The factorial structure that results from the configural invariance testing is used as the baseline to assess the other two levels of invariance (Little, 2013). If the factorial structure described in the base-line model is invariant, this reflects that the construct is conceptualized in the same way across different groups or measurement occasions (Milfont & Fischer, 2010). Therefore, a critical first step when assessing measurement invariance is the confirmation of configural invariance (Karalunas, Bierman & Huang-Pollock, 2016). Metric invariance—or weak factorial invariance—is reached when the loadings of the different manifest indicators of a latent construct are equal across groups or measurement occasions; in other words, the chosen indicators are equally representing the latent construct across groups or measurement occasions. Finally, scalar invariance—or strong factorial invariance—is achieved when the means or intercepts of the indicators are equivalent across groups or measurement occasions (Karalunas, Bierman, & Huang-Pollock, 2016; Little, 2013; Putnick & Bornstein, 2016).

Although the relevance of measurement invariance has been widely acknowledged by researchers over the past decades (Gregorich, 2006; Kern et al., 2016; Knight & Zerr, 2010; Little, 2013; Meredith & Horn, 2001), in most research in the behavioral sciences it has been "simply assumed that if the same test was used in different samples or at different times with the same people, the same attribute was measured" (Meredith & Horn, 2001, p. 205). In most empirical studies—cross-sectional or longitudinal—measurement invariance has been scarcely tested (Gregorich, 2006, Kern et al., 2016; Little, 2013), and when tested, it was predominantly for the goal of test construction and validation across populations (Gregorich, 2006). In general, most of the studies addressing measurement invariance involving young children are focused on multi-group comparisons (multi-group invariance) and considerably less attention has been paid to longitudinal invariance. Even though Kern and colleagues (2016) argue that the exploration of measurement invariance should be a standard first analytical step, especially in longitudinal studies.

2.1.4 Key developmental domains: factor structure and evidence of measurement invariance

In this study we focus on three key developmental domains to exemplify measurement invariance in applied developmental research in young children: pre-academic skills (including early literacy and early numeracy), executive functions as core cognitive skills, and motor skills. Per domain, we will provide a general definition and a description of their particular components.

Pre-academic skills. Pre-academic skills are typically expressed in terms of early numeracy and early literacy skills. Early literacy refers to the acquisition of coding and oral skills, basic knowledge and attitudes that are the foundation for reading and writing (Storch & Loningan, 2002; Whitehurst & Lonigan, 1998). Early numeracy is characterized by three general domains: numbering, numerical relations and arithmetic operations (Purpura, Hume, Sims & Lonigan, 2011), which are preparatory for mathematical achievement (Raghubar & Barnes, 2017). Early numeracy and early literacy are highly interrelated and develop rapidly during the early childhood years (Toll & Van Luit, 2014). Whereas pre-academic skills are usually represented as a single or as two distinctive but related factors—early numeracy and early literacy—its latent structure is not commonly tested explicitly throughout the early childhood years.

Executive functions. Executive functions are considered the "higher order, self-regulatory, cognitive processes that aid in the monitoring and control of thought and action" (Carlson, 2005, p. 595). Traditionally, executive functions includes three basic processes: working memory, that refers to the ability to monitor and revise information; inhibitory control refers to the ability to suppress prepotent responses; and shifting that refers to the ability to switch between multiple tasks (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Relatively, more attention has been paid to the factor structure of executive functions in young children than other developmental domains. Several studies modeling executive functions in children between 3 and 6 years of age, have reported that inhibitory control and working memory are clearly distinguishable but interrelated subdomains (Lerner & Lonigan, 2014; Miller et al., 2012, Karalunas, Bierman, & Huang-Pollock, 2016), and that these subdomains are the foundation for the later development of shifting (Best & Miller, 2010; Garon, Bryson, & Smith, 2008; Senn, Epsy, & Kaufman, 2004). Therefore, in this study, we focus only on working memory and inhibitory control. Despite our rich understanding of the development of executive functions, only few studies have addressed the issue of measurement invariance in young children. For example, Willoughby, Wirth, and Blair (2012) assessed 1,292 children aged 3 to 5 years old in three measurement occasions. They concluded that when executive functions are addressed on the task level, strong measurement invariance was achieved, but when studied in combination as a latent construct, only partial invariance was achieved (with only two out of six tasks being fully invariant). Secondly, Karalunas, Bierman, and Huang-Pollock (2016) studied measurement invariance of executive functions on children age 5 to 6 with (n = 63) and without ADHD (n = 44). They concluded that configural invariance, based on eight tasks in a two-factor model of working memory and inhibitory control, was achieved across groups and across two measurement occasions.

Other studies have utilized measurement invariance to test if the same factorial structure of EF holds across different groups. For example, Wiebe, Epsy and Charak (2008), in a sample of 243 children (2.5 to 6 years old), confirmed a single-factor model of EF including tasks of working memory and inhibitory control. They reported that this model was invariant across gender and socioeconomic status. Similar results were reported by Hughes, Ensor, Wilson and Graham, (2009) in their study including 191 four- to six-year-old children, where they also describe that a single factor structure was a good representation of their data at two-time points. This model was also invariant across gender.

Motor skills. Motor development is described as the process of acquisition of movement patterns and skills (Malina, 2003). In young children, motor development is concentrated around the mastering of fundamental motor skills, which include locomotor, manipulative, and balance skills (Logan et al., 2018, Malina, 2003). These fundamental motor skills are the building blocks of more sophisticated and distinct motor skills, and are expected to be mastered by typically developing children around ages 6 to 8 (Logan et al., 2018). A classical distinction when talking about motor skills is between gross and fine motor skills. Gross motor skills utilize large muscles and comprise balance, orientation, and the movement of trunk and limbs. Fine motor skills require the coordination of small muscles and involve motor precision and integration (Cameron, Cottone, Murrah, & Grissmer, 2016; Van der Fels et al., 2015). The factor structure of motor skills is mainly theoretically driven, and only a few studies have empirically explored their factor structure in young children. For example, Oberer, Gashaj, and Roebers (2017) tested the factor structure of motor skills of 156 six-year-old Swiss children. They tested a single-factor model and a two-factor model with a distinction of fine and gross motor skills. Their results showed that both models had good fit and all indicators were significant. The authors selected the two-factor model (r = .89, p < .001) to represent motor skills as this had a slightly better fit. However, the study conducted by Vatroslav (2011) reports contradictory results. In this study, the author explored the latent structure of motor skills of 230 six-year-old Croatian children. Five sub-dimensions were tested: coordination, flexibility, strength, agility and precision. Nonetheless, the tests favored a different structure with three more general sub-dimensions: coordination with object manipulation, general motor abilities and flexibility. It should be noted that none of these empirical studies has examined measurement invariance of motor skills.

2.1.5 The present study

The present study originates from the observation that despite measurement invariance being a formal requirement for the typical developmental statistical analysis—irrespective of a cross-sectional or longitudinal design—it is rarely explicitly explored. The nature of the data collected in a research project investigating the development of Mexican young children (3 to 6 years of age), enabled us to examine measurement invariance for three developmental domains on two types of research designs. Therefore our aims in this study were: (1) to explore the stability and equality of three developmental domains—pre-academic skills, executive functions and motor skills—and in this way, contribute to their operationalization; and (2) to determine the level of measurement invariance—configural, metric or scalar—for a cross-sectional design (based on data of children from three grades of early childhood education) and a longitudinal design (based on repeated measurements within each child across the early childhood period). By doing this, we strive to open a debate about the limitations of the current research practices and techniques in developmental research and their assumptions, and pondered which level of invariance may suffice to balance the tension created between the changing nature of development in the early childhood period and the assumption of invariance necessary for most of analytical techniques.

2.2 Method

2.2.1 Research context and design

This study is part of a larger research project (Study of the Integral Development of Preschool children, *Estudio del Desarrollo Integral del Preescolar - EDIP*) that addressed the development of Mexican young children (3 to 6 years of age) in multiple domains. This project took place in Mexico City, Mexico. Early childhood education (ECE) in Mexico is obligatory and starts at age 3. Children are expected to complete three grades of ECE before starting primary education: ECE 1 (3 to 4 years old), ECE 2 (4 to 5 years old) and ECE 3 (5 to 6 years old). In collaboration with the Preschool Sectorial Directorate from the Ministry of Education, five public ECE centers from the urban area of Mexico City were recruited to participate. As the focus was on typically developing children, those identified by the Special Needs Education Unit were not considered for participation. A longitudinal assessment was planned including four measurement occasions: January 2016, June 2016, January 017 and June 2017.

2.2.2 Participants

The final sample was utilized for two different analytical approaches (see Table 2.1). The cross-sectional sample is based on the information gathered at measurement occasion 1, and consisted of 371 typically developing young children divided as follows: 127 children from cohort 1 - ECE1 (M_{age}= 44.11 months; *SD* = 3.83 months), 139 from cohort 2 - ECE 2 (M_{age} = 55.86 months; *SD* = 3.52 months) and 105 from cohort 3 - ECE 3 (M_{age} = 68.01; *SD* = 3.41 months). For the longitudinal study, only cohort 1 and cohort 2 were further assessed in four measurement occasions (as further explained in the 'Research context and design' section), which were then transformed into six time points by means of an accelerated longitudinal design, covering in this way the entire three-year ECE period as illustrated in Table 2.1.

Table 2.1 *Transformation of the longitudinal data collection into the accelerated longitudinal design*

Original format of longitudinal data collection						
	M1	M2	M3	M4		
Cohort 1 *n* (ECE1)	127	127	98	103		
Cohort 2 *n* (ECE 2)	139	140	115	121		
Cohort 3[a] *n* (ECE 3)	105	x	x	x		
Accelerated longitudinal design						
	ECE 1 Halfway[b] (T1)	ECE 1 End[c] (T2)	ECE 2 Halfway[b] (T3)	ECE 2 End[c] (T4)	ECE 3 Halfway[b] (T5)	ECE 3 End[c] (T6)
Cohort 1						
'Younger cohort'	M1	M2	M3	M4	*	*
Cohort 2						
'Older cohort'	*	*	M1	M2	M3	M4

Note. M = measurement occasion, ECE 1 = first grade of early childhood education, ECE 2 = second grade early childhood education, ECE 3= third grade of early childhood education, T = time point, x = not assessed, * = imputed data missing by design. Data used for the cross-sectional analysis is marked with a double border; data used for the longitudinal design is marked in light gray. In the cross-sectional design the cohorts represent the three grades of early childhood education in Mexico, whereas in the accelerated longitudinal design the cohorts represent the source of information on each time point. Therefore we will use "grade" when referring to the cross-sectional design, and "time points" when referring to the longitudinal design.

The longitudinal sample consisted of 279 children: 134 from cohort 1 (beginning ECE 1 to halfway ECE 2), and 145 from cohort 2 (halfway ECE 2 to end ECE 3). The discrepancy between the cross-sectional and longitudinal sample is due to the addition of 13 children (7 children of cohort 1 and 6 children of cohort 2) in the longitudinal study. These children were registered to participate in the study but were absent in the first measurement occasion and re-joined in the second measurement occasion, therefore they are not included in the cross-sectional sample.

Table 2.2 provides an overview of sociodemographic characteristics of the sample, based on mother educational level and monthly household income. Mother educational level was based on the International Standard Classification of Education of UNESCO. Household monthly income was assessed using Mexico's 2012 household income deciles (INEGI, 2012). As the study includes public ECE centers in low socioeconomic areas, nine ranges of household income were created based on the five lower deciles. About 64% of our sample reported a monthly household income corresponding to the first lower decile of the average household income of the country (less than 7,000 Mexican pesos, about 375 USD). For the cross-sectional design, no significant differences were found between the three cohorts for mother educational level, $\chi^2(8) = 7.89$, $p = .44$. Monthly income was significantly different, $\chi^2(14) = 25.56$, $p = .02$; however, post-hoc analysis with pairwise comparison per group showed non-significant differences— cohort 1 vs. cohort 2, $\chi^2(8) = 12.11$, $p = .14$; cohort 1 vs. cohort 3, $\chi^2(7) = 9.52$, $p = .21$; cohort 2 vs. cohort 3, $\chi^2(6) = 9.62$, $p = .14$. For the longitudinal design, no significant differences were found for mother educational level, $\chi^2(5) = 4.96$, $p = .42$, and monthly income, $\chi^2(8) = 12.11$, $p = .14$.

2.2.3 Procedure

Parents or guardians of the children gave written consent for their children to participate. Ethical approval was granted by the Ethics Committee of Pedagogical and Educational Sciences of the University of Groningen. For the evaluation of the children, six assessors were recruited and trained before the testing period. Assessors were all Mexican, graduate psychologists or psychology students with sufficient mastery of the testing procedures as demonstrated in practice sessions. Children were assessed individually in a separate testing room (e.g., the school library) in pull-out sessions during regular school hours. The complete testing battery was divided into two one-on-one sessions of approximately 15 to 20 minutes each conducted on separate days, and a 20-minute group session to test motor skills. The group session

Table 2.2 *Sociodemographic characteristics of the sample*

	Cohort 1	Cohort 2	Cohort 3
Mother educational level (%)			
Pre-primary education	0	0.7	2.0
Primary education	13.8	12.1	17.2
Lower secondary education	40	30.7	31.3
Upper secondary education	26.9	37.1	35.4
Bachelor degree, specialization or master degree	19.2	19.3	14.1
Monthly income (%)			
Range 1-2 (1st decile)	66.9	61.2	65.7
Range 3-4 (2nd decile)	13.1	23.7	13.7
Range 5-6 (3rd decile)	12.3	9.4	15.7
Range 7-8 (4th decile)	4.6	0.7	2.0
Range 9 (5th decile or higher)	3.1	5.0	2.9
Sex (% female)	60.4	54.5	55.2
Age in months (M) longitudinal design			
T1 Halfway ECE1	43.7	43.6	
T2 End ECE1	47.4	47.3	
T3 Halfway ECE2	54.9	55.6	
T4 End ECE2	59.5	59.3	
T5 Halfway ECE3	66.9	66.7	
T6 End ECE3	71.5	71.2	

was conducted at the school's gym or music room, where a circuit of the motor tasks was arranged to evaluate several children simultaneously.

2.2.4 Instruments

Pre-academic skills. We assessed pre-academic skills utilizing two tests of early numeracy and two tests of early literacy. For early numeracy we used the tests of applied problems and quantitative concepts (form A) of the Woodcock-Johnson Battery III, Achievement tests, Spanish-form (WJ III *Pruebas de aprovechamiento*; Muñoz-Sandoval, Woodcock, McGrew, & Mather, 2005). In applied problems, children were asked to recognize quantities and solve basic numerical problems.

In quantitative concepts, children were confronted with numerical concepts such as big-small, counting, identification of numbers and mathematical vocabulary and symbols. For early literacy we applied two subtests of the Woodcock-Muñoz Language Survey Revised, Spanish Form (WMLS-R; Woodcock, Muñoz-Sandoval, Ruef, & Alvarado, 2005), i.e., letter-word identification and picture vocabulary. In letter-word identification, children had to recognize the graphical representation of letters and words and fluently read basic words. In picture vocabulary, children were asked to name a series of images of objects.

The score in these tasks is represented by the number of correct answers. Internal consistency was based on the first measurement occasion including the three years of ECE, and Cronbach's alpha was calculated for the four subtests used. All subtests showed acceptable internal consistency: Picture vocabulary (α = .91), Letter-word identification (α = .95), Applied problems (α = .89) and Quantitative concepts (α = .77).

Executive functions. We included tasks of inhibitory control and working memory from the Neuropsychological Battery for Preschoolers (*Batería neuropsicológica para preescolares*, BANPE; Ostrosky, Lozano, & González-Osornio, 2016). For inhibitory control we used two tasks: day-night and angel-devil. In the day-night task the child was presented with two cards, one depicting the sun and one depicting the moon. The child was asked to say "day" when a moon-card was shown and "night" when a sun-card was presented. The score represents the amount of correct trials out of 16. For the angel-devil task the child was asked to follow the instructions given by the angel but ignore the instructions given by the devil. The score represents the performance on the devil trials, with a maximum of 12 points.

For working memory, we used digits backward and blocks backward. Digits backward is a verbal task where the child was asked to repeat series of numbers that the assessor mentioned in inverse order, starting with a series of two digits up to a maximum of six digits. The score represents the maximum length achieved (e.g., three digits successfully repeated in the inverse order corresponds to a score of 3). The maximum score is 6. Blocks backward is a visuospatial task in which children were presented with a panel of 3x3cm wooden blocks distributed horizontally on a plank, and were asked to point in the inverse order the blocks that the assessor had previously pointed out. The assessor started with a series of two blocks up to a maximum of six blocks. The score represents the amount of successfully inverse-pointed blocks, with a maximum score of 6.

Motor skills. We used the Movement Assessment Battery for Children-2 (MABC-2; Henderson, Sugden, & Barnet, 2007) which assesses fundamental motor skills. We utilized the age band 1—appropriate for children of 3 to 6 years of age—consisting of eight tasks divided in three theoretical components: manual dexterity (posting coins, threading beads and drawing trial) aiming and catching (throwing and catching a bean bag), and balance (one-leg balance, walking with heels raised, and jumping on mats).

For posting coins, children were asked to place coins into a bank box as fast as they could. The final score is the average time in seconds of the best performance of each hand. In threading beads, children were asked to thread plastic beads into a lace as fast as they could. The score represents the fastest performance in seconds. For the drawing trial, children had to follow a basic labyrinth without going outside of the borders. The score represents the number of errors; extreme values were fixed to the maximum value of three standard deviations. For these three tasks the final scores were reverse coded. For the throwing task, children were asked to throw a beanbag onto a mat that was placed 1.8 meters away from them. The score represents the amount of successful throws out of 10. For the catching task, children were asked to catch a beanbag that was thrown to them from a distance of 1.8 meters. The score represents the amount of successful catches out of 10. In the one-leg balance task, children were asked to keep the equilibrium while standing on one leg. The score represents the average of the best performance achieved for each leg. All tasks had a practice trial before the definitive assessment.

Within this age band, some tasks have two distinct versions based on age: 3- and 4-year-olds and 5- and 6-year-olds. The versions vary in the amount of stimuli received (posting coins and threading beads) or in the scoring rule (catching beanbag and jumping on mats). To ensure comparability, we performed an age-correction of the scores by calculating regression lines for the standardized performance by age in months and then adding or subtracting the difference in the intercept coefficients at 60 months (age of the change of version).

2.2.5 Missing Data

In the cross-sectional design, the proportion of missing information ranged from 1.1% to 7.5% on the variable level, which was handled by Full Information Maximum Likelihood. In the longitudinal design, we had two sources of missing information: data missing by design and missing not-by-design. The data missing by design stem from four time points of our accelerated longitudinal design—time 1, time 2, time 5 and time 6—which are marked with asterisks in Table 2.1. This type of missing information is considered to be Missing Completely at Random (MCAR), because the missing mechanism is controlled by the researcher, and therefore it can be confidently treated with modern techniques for handling missing data (Little, 2013). The missing not-by-design refers to unexpected missings (e.g., dropout or absence during evaluation). From the final sample of the longitudinal design (n = 279) about 70% of the children completed four assessments (n = 194), 14.33% completed three assessments (n = 40), 13.97% completed two assessments (n = 39), and 2.15% (n = 6) completed only one assessment. We simultaneously conducted multiple imputation for both types of missing data with the help of the Multivariate Imputation by Chained Equations (MICE) package in R (Van Buuren & Groothuis-Oudshoorn, 2011). More information about the imputation process is provided in Appendix A.

2.2.6 Analytical Strategy

Analyses for both designs—cross-sectional and longitudinal—were conducted separately using Mplus version 7.3 (Muthén & Muthén, 2015). First, we conducted a factor analysis to identify the model that best suits the data on the three constructs of interest—pre-academic skills, executive functions, and motor skills. This was done by testing both general models (i.e., including the three grades or the six time points), and specific models per grade or time point. Two models were tested for pre-academic skills: one of a single general factor and one including a distinction between pre-numeracy and pre-literacy. Two models were tested for executive functions: one of a single general factor, and one including a distinction between inhibitory control and working memory. Finally, three models were tested for motor skills: one with a single general factor, one including a distinction between fine and gross motor skills, and one including the proposed structure of the movement ABC—manual dexterity, aiming and catching, and balance (Henderson, Sugden, & Barnet, 2007).

For testing measurement invariance we followed a bottom-up approach—starting with a non-restricted model and building up to more restrictive models—by testing first configural invariance, then metric invariance, and finally scalar invariance. The assessment criteria of these models adhered to the recommendations of Cheung and Rensvold (2002). At the configural level, the overall model fit was considered based on various indicators: Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker Lewis Index (TLI), and Standardized Root Mean Square Residual (SRMR). Additionally, χ^2 is reported whenever possible for informational purposes. The general recommended cut-off values of these fit indices are for RMSEA and SRMR a value < .05 for good fitting models and < .08 for acceptable models, and for CFI and TLI > .90 for acceptable models and > .95 for good fitting models. We used these generally accepted cut-off values as a reference, but we also followed a more holistic approach and made decisions about the model fit based on the overall fit as well as significance and interpretability of the models. Configural invariance in the cross-sectional design was assessed first on a general sample including the three ECE grades and later trying to replicate the same model for each grade separately. For the longitudinal design a general model including all six time points was first defined, and afterwards each time point was modeled independently. For the metric and scalar models, invariance decisions were made based on delta CFI, and delta Gamma-hat as these indicators have proven to be independent of model complexity, sample size, and other fit measures (Fan & Sivo, 2007). General cut-off values for delta CFI, and delta Gamma-hat are < .01 and < .001, respectively (Cheung & Rensvold, 2002). Gamma-hat was calculated with an online calculator (retrieved from: http://www.education.auckland.ac.nz/en/about/research/research-at-faculty/quant-dare-unit_1/tools-for-statistical-procedures.html) based on the formula provided by Fan and Sivo (2007):

$$Gamma\ hat = \frac{\text{number of observed variables}}{\text{number of observed variables} + (2 * df * RMSEA^2)}$$

Metric invariance was tested in a stepwise manner, first including all grades or time points that achieved configural invariance. Secondly, by a pairwise fitting, that is, first by including the subsequent grade or time point—e.g. ECE 1 ECE 2 (cross-sectional) or time 1 and time 2 (longitudinal)—and if this model achieved metric invariance the next grade or time point was added. If metric invariance was not achieved we proceeded by fitting the next pairwise model—e.g. ECE 2 and ECE 3 (cross-sectional) or time 2 and time 3 (longitudinal)—and so on. Scalar invariance was only tested for those models that achieved configural and metric invariance.

2.3 Results

Table 2.3 presents the models that were tested for the general factor structure of the three domains—pre-academic skills, executive functions, and motor skills—in the cross-sectional design (including the three grades) and the longitudinal design (including the six time points). An extra column of 'additional information' is presented to provide qualitative remarks or signs of inappropriate model solutions that may not be directly derived from the fit indices.

In the search for an appropriate structure for motor skills, we tested two models with two factors: 'Two factors A' and 'Two factors B'. In the 'Two factors A' model, the fine motor factor was composed of three tasks: posting coins, threading beads and drawing trial. In the 'Two factors B' model, the drawing trail was allowed to belong to the gross motor factor instead of to the fine motor factor, because an exploratory factor analysis had shown that this task seemed to constantly switch among factors. For the cross-sectional design, on the general level—including the three grades—a single factor model was preferred for pre-academic skills, $\Delta\chi^2 = 1.305$, $\Delta df = 1$, $p = .25$, and for executive functions, $\Delta\chi^2 = 1.57$, $\Delta df = 1$, $p = .21$. For motor skills, the two-factor model (version B) was preferred $\Delta\chi^2 = 10.132$, $\Delta df = 1$, $p = .001$. For the longitudinal design, on the general level—including the six time points—a single factor model was preferred for pre-academic skills, $\Delta\chi^2 = .948$, $\Delta df = 1$, $p = .32$, and executive functions ($\Delta\chi^2$ not computed due to improper model solution); whereas for motor skills, a two-factor model (version B) was preferred, $\Delta\chi^2 = 88.63$, $\Delta df = 1$, $p < .001$.

2.3.1 Configural invariance

Tables 2.4 and 2.5 summarize the results of the models tested per domain for the cross-sectional and longitudinal designs, respectively. An extra column of 'additional information' is presented to provide qualitative remarks or signs of inappropriate model solutions that may not be directly derived from the fit indices. The results of the chi-square difference test of each model comparison for both designs are then presented in Table 2.6 (only models with an appropriate solution were considered for model comparison). The factor loadings of the final selected models per domain are reported in the Appendix B.

Table 2.3 *General factor structure per domain and design*

Design	Domain	Model	χ^2	*df*	*p*	RMSEA	CFI	TLI	SRMR	Additional information
Cross-sectional	Pre-academic skills	Single factor	1.31	2	0.51	0.00	1.00	1.00	0.01	
		Two factors	0.01	1	0.94	0.00	1.00	1.06	0.00	*r* = .97
	Executive functions	Single factor	2.06	2	0.35	0.01	1.00	0.99	0.01	
		Two factors	0.49	1	0.48	0.00	1.00	1.01	0.01	*r* = .89
	Motor skills	Single factor	32.19	20	0.04	0.04	0.97	0.97	0.03	
		Two factors A	31.45	19	0.04	0.04	0.98	0.97	0.03	*r* > 1
		Two factors B	22.06	19	0.28	0.02	0.99	0.99	0.03	*r* = .83
		Three factors	29.21	17	0.03	0.05	0.97	0.96	0.03	*r* > 1, 'Balance' not positive definite
Longitudinal	Pre-academic skills	Single factor	3.32	2	0.19	0.02	0.99	0.99	0.01	
		Two factors	2.37	1	0.12	0.03	0.99	0.99	0.01	*r* > 1
	Executive functions	Single factor	6.94	2	0.03	0.04	0.99	0.97	0.01	
		Two factors	0.002	1	0.96	0.00	1.00	1.01	0.00	*r* = .86
	Motor skills	Single factor	162.45	20	0.00	0.06	0.86	0.8	0.05	
		Two factors A	137.4	19	0.00	0.06	0.89	0.83	0.05	*r* = .83
		Two factors B	73.81	19	0.00	0.04	0.94	0.92	0.03	*r* = .71
		Three factors	133.30	17	.000	0.06	0.88	0.81	0.05	*r* > 1, negative loading of Drawing trial

Note. *df* = degrees of freedom.

Cross-sectional design. Table 2.4 presents the models tested per domain and per grade for the cross-sectional design. None of the domains reached full configural invariance. However, partial configural invariance was achieved in pre-academic skills and executive functions when including only the oldest grades (ECE2 and ECE3). For pre-academic skills and executive functions, only ECE2 and ECE3 were best represented by a single factor model, in the case of ECE1 neither a single- nor a two-factor model showed an appropriate solution. For motor skills, a single factor model better represented ECE1; however, for ECE2 and ECE3 none of the proposed models showed appropriate solutions.

Longitudinal design. Table 2.5 presents the models per domain and per time point for the longitudinal design. None of the domains reached full configural invariance, but only partial configural invariance. For pre-academic skills, the best fitting model was also the single factor model from time 2 to time 6. Time 1 did not yield an appropriate solution. For motor skills, the best fitting model was the two-factor model (version B) from time 1 to time 4. At time 5 and time 6, none of the models had a good fitting solution. In the case of executive functions, neither a single factor nor a two-factor model could not be identified for most of the time points; that is, only time 3 and time 5 showed an appropriate model solution, and at both time points a single factor model was preferred.

Table 2.4 *Overview of factor structure models per domain, cross-sectional design*

Domain	Model	Group	χ^2	*df*	*p*	RMSEA	CFI	TLI	SRMR	Additional information
Pre-academic skills	Single factor	ECE 1	10.89	2	.00	.18	.92	.76	.05	
		ECE 2	5.75	2	.05	.11	.97	.92	.03	
		ECE 3	3.70	2	.15	.09	.98	.95	.03	
	Two factors	ECE 1	5.78	1	.01	.19	.95	.74	.03	$r = .74$
		ECE 2	2.11	1	.14	.09	.99	.95	.02	$r > 1$
		ECE 3	2.46	1	.11	.11	.98	.92	.02	$r = .87$
Executive functions	Single factor	ECE 1	0.36	2	.83	.00	1.00	1.00	.01	None significant indicator
		ECE 2	1.90	2	.38	.00	1.00	1.00	.03	
		ECE 3	1.94	2	.37	.00	1.00	1.00	.03	
	Two factors	ECE 1	0.33	1	.57	.00	1.00	1.00	.01	$r > 1$, not computed standard errors, latent covariance matrix of working memory not positive definite.
		ECE 2	0.08	1	.78	.00	1.00	1.18	.01	$r = .57$
		ECE 3	-	-	-	-	-	-	-	No convergence

Note. ECE= early childhood education, *df* = degrees of freedom. Best performing models are highlighted by gray-marked cells.

Table 2.4 *Overview of factor structure models per domain, cross-sectional design* (continuation)

Domain	Model	Group	χ^2	*df*	*p*	RMSEA	CFI	TLI	SRMR	Additional information
Motor skills	Single factor	ECE 1	24.60	20	.21	.05	.95	.93	.05	
		ECE 2	25.81	20	.17	.05	.85	.80	.06	
		ECE 3	25.62	20	.17	.05	.77	.69	.07	Only 4 significant indicators
	Two factors A[a]	ECE 1	24.00	19	.19	.05	.95	.93	.05	r = .91, Catching not significant
		ECE 2	25.76	19	.13	.05	.82	.74	.06	$r > 1$
		ECE 3	23.07	19	.23	.05	.83	.76	.07	$r > 1$
	Two factors B[b]	ECE 1	21.17	19	.32	.03	.97	.97	.05	r = .78
		ECE 2	24.45	19	.18	.05	.86	.80	.06	r = .71
		ECE 3	23.90	19	.20	.05	.80	.71	.06	r = .63, Gross factor only two significant indicators.
	Three factors	ECE 1	22.61	17	.16	.05	.95	.91	.05	'Balance' not positive definite, 'Aiming and catching' indicators not significant
		ECE 2	21.24	17	.21	.04	.89	.82	.05	$r > 1$, 'Balance' not positive definite, 'Aiming and catching' indicators not significant
		ECE 3	-	-	-	-	-	-	-	No convergence

Note. ECE= early childhood education, *df* = degrees of freedom, [a] Fine motor skills (posting coins, threading beads and drawing trail) and gross motor skills (catching, throwing, one-leg balance, walking in a line, and jumping on mats). [b] Fine motor skills (posting coins, and threading beads) and gross motor skills (catching, throwing, one-leg balance, walking in a line, jumping on mats and drawing trail). Best performing models are highlighted by gray-marked cells.

Table 2.5 *Overview of factor structure models per domain, longitudinal design*

Domain	Model	Time	Rep	$\chi 2$	*df*	*p*	RMSEA	CFI	TLI	SRMR	Additional information
Pre-academic skills	Single factor	1	5	13.38	2	.00	.14	.88	.65	.05	
		2	5	2.11	2	.34	.01	.99	.99	.02	
		3	5	8.60	2	.01	.10	.97	.90	.03	
		4	5	3.66	2	.16	.05	.99	.97	.02	
		5	5	.20	2	.90	.00	1.00	1.18	.01	
		6	5	4.31	2	.11	.06	.97	.91	.03	
	Two factors	1	5	5.00	1	.02	.12	.96	.76	.03	$r = .63$
		2	5	1.44	1	.22	.04	.99	.97	.01	$r > 1$
		3	5	2.89	1	.08	.08	.99	.94	.02	$r > 1$
		4	5	3.15	1	.08	.09	.99	.93	.02	$r > 1$
		5	5	2.55	1	.11	.07	.95	.68	.01	$r = .93$
		6	5	2.85	1	.09	.08	.97	.85	.02	$r > 1$
Executive functions	Single factor	1	2	-	-	-	-	-	-	-	χ^2 not computed [a]
		2	1	1.39	2	.49	.00	1.00	1.42	.02	None indicator significant
		3	5	1.49	2	.47	.00	1.00	1.02	.02	
		4	5	6.29	2	.04	.09	.90	.72	.04	
		5	5	0.49	2	.78	.00	1.00	1.22	.01	Angel-devil not significant
		6	4	-	-	-	-	-	-	-	χ^2 not computed [a]

Note. Rep = number of replications, *df* = degrees of freedom. Best performing models are highlighted by gray-marked cells.

Table 2.5 *Overview of factor structure models per domain, longitudinal design* (continuation)

Domain	Model	Time	Rep	χ^2	*df*	*p*	RMSEA	CFI	TLI	SRMR	Additional information
Executive functions	Two factors	1	2	-	-	-	-	-	-	-	χ^2 not computed [a]
		2	2	-	-	-	-	-	-	-	χ^2 not computed [a]
		3	5	.42	1	.51	.00	1.00	1.04	.01	*r* = .78
		4	5	.01	1	.91	.00	1.00	1.12	.01	*r* = .52
		5	4	-	-	-	-	-	-	-	χ^2 not computed [a]
		6	3	-	-	-	-	-	-	-	χ^2 not computed [a]
Motor skills	Single factor	1	5	16.24	20	.70	.00	1.00	1.05	.04	
		2	5	17.84	20	.59	.00	1.00	1.06	.04	
		3	5	33.73	20	.03	.05	.83	.77	.06	
		4	5	37.59	20	.01	.05	.81	.73	.06	
		5	5	14.33	20	.81	.00	1.00	1.68	.04	Only two significant indicators
		6	5	15.38	20	.75	.00	1.00	1.27	.05	Only four significant indicators
	Two factors A[b]	1	5	16.30	19	.63	.00	1.00	1.04	.03	*r* = .91
		2	5	16.44	19	.62	.00	1.00	1.07	.03	*r* = .71
		3	5	29.33	19	.06	.04	.88	.82	.06	*r* = .60
		4	5	17.50	19	.55	.00	1.00	1.02	.04	*r* = .35
		5	4	87.97	19	.00	.11	.00	-6.32	.03	Gross factor with no significant indicator
		6	5	9.42	19	.96	.00	1.00	1.59	.03	No significant indicator

Note. Rep = number of replications, *df* = degrees of freedom, [a] due to large amount of missing information or insufficient number of imputations, [b] Fine motor skills (posting coins, threading beads and drawing trial) and gross motor skills (catching, throwing, balance in one leg, walking in a line, and jumping on mats). Best performing models are highlighted by gray-marked cells.

Table 2.5 *Overview of factor structure models per domain, longitudinal design* (continuation)

Domain	Model	Time	Rep	χ^2	*df*	*p*	RMSEA	CFI	TLI	SRMR	Additional information
Motor skills	Two factors B[c]	1	5	14.76	19	.73	.00	1.00	1.06	.03	*r* = .79
		2	5	6.71	19	.99	.00	1.00	1.33	.03	*r* = .53
		3	5	15.12	19	.71	.00	1.00	1.07	.04	*r* = .41
		4	5	13.06	19	.83	.00	1.00	1.09	.03	*r* = .35
		5	3	16.60	19	.61	.00	1.00	1.27	.03	Only two significant indicators
		6	5	7.42	19	.99	.00	1.00	1.71	.03	Only two significant indicators
	Three factors	1	4	14.89	17	.60	.00	1.00	1.03	.03	*r* > 1, 'Aiming and catching' indicators not significant, ‘Balance’ not positive definite
		2	5	40.54	17	.00	.07	.57	.28	.03	*r* > 1, 'Aiming and catching' indicators not significant
		3	5	50.77	17	.00	.08	.60	.34	.05	'Aiming and catching' indicators not significant, no significant correlation among factors.
		4	4	25.58	17	.08	.04	.91	.85	.04	'Aiming and catching' indicators not significant, residual covariance of Catching not positive definite
		5	5	50.02	17	.00	.08	.00	-3.71	.03	No significant indicator
		6	5	6.25	17	.99	.00	1.00	1.70	.03	Only three significant indicators

Note. Rep = number of replications, *df* = degrees of freedom, a due to large amount of missing information or insufficient number of imputations, [c] Fine motor skills (posting coins, and threading beads) and gross motor skills (catching, throwing, balance in one leg, walking in a line, jumping on mats and drawing trial). Best performing models are highlighted by gray-marked cells.

Table 2.6 *Model comparison for configural invariance*

Design	Model	Group/Time	$\Delta\chi^2$	Δdf	*p*
Cross-sectional	Pre-academic skills	ECE2	3.64	1	.06
		ECE3	1.24	1	.27
	Executive functions	ECE2	.03	1	.86
		ECE3	1.83	1	.18
	Motor skills [a]	ECE1	3.43	1	.06
Longitudinal [b]	Executive functions	T3	1.49	1	.22
		T5	0.49	1	.48
	Motor skills [a]	T1[c]	1.49	1	.22
		T2	11.13	1	.00
		T3	18.61	1	.00
		T4	12.01	1	.01

Note. [a] Comparison of single factor versus two factors B. [b] Pre-academic skills is not reported as none of the models based on two factors had an appropriate solution. [c] For practical purposes, the two factor model was selected as the final solution, as both models—single factor and two factors—showed good fit.

2.3.2 Metric and scalar invariance

Models that achieved at least partial configural invariance were subsequently tested for metric invariance: pre-academic skills cross-sectional (including ECE2 and ECE3) and longitudinal (from time 2 to time 6); executive functions cross-sectional (including ECE2 and ECE3) and longitudinal (including only time 3 and 5); and motor skills longitudinal (from time 1 to time 4). Table 2.7 presents the results of the models tested for metric invariance. Considering the delta CFI and delta gamma hat thresholds, metric invariance was only achieved for (a) pre-academic skills in the longitudinal design from time 3 to time 4 showed metric invariance, and (b) executive functions in the cross-sectional design from ECE2 to ECE3. For motor skills, metric invariance was achieved from time 1 to time 4. Additionally, for those models that achieved metric invariance we also tested for scalar invariance. None of these models achieved scalar invariance (see Table 2.7).

Table 2.7 *Overview of models testing metric and scalar invariance*

Model			χ^2	*df*	*p*	CFI	RMSEA	Gamma hat	Δ CFI	Δ Gamma
Pre-academic skills										
Cross	ECE2-ECE3	Configural	9.46	4	.05	.98	.11	.976		
		Metric	17.97	7	.01	.96	.11	.959	.02	.017
Long	T2-T6	Configural	12.44	10	.25	.99	.03	.995		
		Metric	110.73	22	.00	.81	.12	.860	.17	.135
	T2-T3	Configural	9.66	4	.04	.98	.07	.990		
		Metric	28.58	7	.00	.93	.11	.962	.05	.028
	T3-T4	Configural	12.62	4	.01	.98	.09	.985		
		Metric	**14.83**	**7**	**.04**	**.98**	**.06**	**.986**	**.00**	**-.001**
		Scalar	55.02	11	.00	.90	.12	.926	.09	.060
	T4-T5	Configural	1.67	4	.80	1.00	.00	1.000		
		Metric	14.74	7	.04	.95	.06	.986	.05	.014
	T5-T6	Configural	2.36	4	.67	1.00	.00	1.000		
		Metric	12.20	7	.09	.94	.05	.991	.06	.009
Executive functions										
Cross	ECE2-ECE3	Configural	3.85	4	.43	1.00	.00	1.000		
		Metric	**7.01**	**7**	**.43**	**1.00**	**.00**	**1.000**	**.00**	**.000**
		Scalar	79.53	11	.00	.00	.23	.780	1.00	.220
Long	T3-T5	Configural	1.87	4	.75	1.00	.00	1.000		
		Metric	8.95	7	.25	.97	.03	.996	.03	.004
Motor skills										
Long	T1-T4	Configural	48.50	76	.99	1.00	.00	1.000		
		Metric	**94.54**	**94**	**.46**	**.99**	**.00**	**.999**	**.01**	**.001**
		Scalar	1259.94	118	.00	.00	.18	.494	.99	.505

Note. Cross= crossectional, Long= longitudinal.

2.4 Discussion

Our study aimed to explore the stability and equality of three developmental domains—pre-academic skills, executive functions and motor skills— by determining their level of measurement invariance for a cross-sectional and a longitudinal design. By doing so, we strived to open a debate about the tension present between the current research practices and techniques in developmental research and the developmental characteristics of young children.

2.4.1 Factorial structure of the three developmental domains

Our exploration of the general models—i.e., considering the entire ECE period in the cross-sectional (three ECE grades) and longitudinal designs (six time points)—indicated that pre-academic skills and executive functions were best represented by a single factor model, whereas a two-factor model—based on the fine and gross distinction—was preferred for motor skills. Moreover, the general models had a better model fit and mainly yield appropriate solutions more easily than specific models based on time points or grades, except for executive functions in the longitudinal design. Whereas general models—i.e., with aggregated data—showed a very good model fit, when data were analyzed separately—per grade or time point—good model fit was difficult to attain and different improper solutions were found. This is a reflection of the lack of full configural invariance, as the structure defined at the general level was not always replicated when analyzed separately. In other words, at least in some grade or time point, the general structure was not a good representation of the data at that specific developmental moment. The discrepancy between general and specific models was previously highlighted in other studies. For example, regarding the development of executive functions, researchers have warned that the representative structure of executive functions may be different when more specific age ranges are explored (Howard, Okely, & Ellis, 2015; Senn, Espy, & Kaufman, 2004). In the same line, Malina (2013) reported that the development of motor skills may appear as continuous when taking average trends of an aggregated group of children but this may be hiding the real variability among children. Our results underscore the importance of analyzing developmental characteristics not only on an aggregated level, but also trying to untangle them into more specific moments.

It should be noted that in the three domains, certain developmental moments showed a good model fit for a single-factor model and for a two-factor model. This suggests that the constant fluctuation between 'unity and diversity'—a characteristic of executive functions described by Miyake and colleagues (2000)—may actually be applicable for describing other developmental domains throughout the early childhood period as well—sometimes more united than diverse, and sometimes more diverse than united. In such cases, the final decision was made based on parsimony or to favor construct continuity. Furthermore, we are aware that although the final model solutions showed an acceptable representation of the structure of each of the three domains, these structures may not be the best possible representation of the factor structures on each time point or grade. Deeper analysis could be performed to determine the best possible solution for each specific occasion, e.g., the deletion of specific tests or the inclusion of more specific subdomains. Nonetheless, our aim was to find a common factor structure that fitted the data well in a range of different ECE grades or time points. In this sense, sacrifices on accuracy were needed in favor of the generalizability of the factor models.

Another interesting finding was the particular case of the factor structure of motor skills, as we did not find the three-factor structure proposed by the MABC-2 test: 'Aiming and catching', 'Balance' and 'Manual dexterity'. Although the MABC-2 test is widely used in developmental research, to our knowledge, only two studies have tested the factor structure of the MABC-2 in young children (age band 1, from 3 to 6 years). Hua, Gu, Meng, and Wu (2013) explored the factor structure of MABC-2 in 1,823 Chinese children from 36 to 72 months old. The three-factor model showed a poor fit, and only after the deletion of the drawing trial and walking a line—due to extremely low loadings—a good fit was achieved. Ellinoudis and colleagues (2011) replicated the MABC-2 three-factor structure via confirmatory factor analysis on a sample of 183 Greek young children from 36 to 64 months old. It seems that assuming a factor structure, even the one proposed by a well-established instrument, can be risky as it may not be an appropriate representation of the construct in the particular sample and in a particular developmental moment.

2.4.2 Measurement invariance of the three domains in a cross-sectional and longitudinal design

When testing for measurement invariance, we were conscious of the accelerated and non-linear development of young children and therefore we did not expect our measures to be fully invariant. Congruent to our expectations, none of the three developmental domains were fully configural invariant, as none of our measures showed a common factor structure that appropriately covered the entire early childhood period (from ECE 1 to ECE 3, or from time point 1 to time point 6). However, partial configural invariance was achieved for pre-academic skills and executive functions when addressing only the older children—last grades of ECE or last time points, whereas, for motor skills, this was achieved only for the younger children—first grades of ECE or first time points. Such a pattern might be related to the developmental sensitivity of the measures. For example, some of the pre-academic tasks and executive function tasks were too difficult when the children were younger (e.g., quantitative concepts or digits backward), whereas some of the tasks of motor skills were too easy for older children (e.g., jumping on mats). The ceiling and floor effects detected in some of the tasks might be the reason for the lack of an appropriate common representation of the latent construct. Furthermore, the fine and gross factors seem to be more closely related to each other when children are younger and become more differentiated as children get older (for example, r = .80 at Time 1, but r = .35 at Time 4), which is in line with Vatroslav (2011). This could also explain why the proposed factor structures did not work for the oldest children (ECE 2 and ECE3; time 5 and time 6). Maybe an even more differentiated structure is needed as children grow older.

Additionally, we performed the invariance testing for a cross-sectional and a longitudinal design. We observed similarities and differences in both designs. Regarding metric and scalar invariance, only partial metric invariance was achieved for executive functions in the cross-sectional design and for pre-academic skills and motor skills in the longitudinal design. However, the general lack of metric and scalar invariance raises a methodological dilemma: whereas the differences in factor structure may represent more accurately the characterization of the construct in a specific developmental moment, such differences also violate the assumption of invariance needed to perform most of the traditional longitudinal statistical analyses. These findings do not mean that the constructs cannot be assessed properly in the ECE period; however, researchers should proceed carefully when modeling them as a latent variables or use alternative forms of representing the constructs (e.g., a person-centered approach). Although we only achieved partial configural and metric invariance for some domains and depending on the design, it should be noted that previous research has pointed out the value of a failed attempt for invariance. On the one hand, lack of invariance is in itself very informative for the development of the construct of interest, and provides valuable information about the differential processes across groups (e.g., grades) and measurements occasions (e.g., time points) (Kern et al., 2016; Petersen et al., 2016). On the other hand, we should contemplate that latent constructs are only an approximate representation of the construct, but not the construct itself. Thus, as suggested by Meredith and Horn (2001), some space for misfit should be allowed and other alternatives of representing the construct may be explored.

Perhaps one of the most notorious differences between the longitudinal and the cross-sectional design was related to executive functions. In the cross-sectional design, partial metric invariance was achieved, whereas in the longitudinal design a common factor structure was not obtained in most of the time points. Forasmuch as testing cross-sectional invariance is a good practice—and may work as a proxy of the longitudinal data—it seems to be not enough to support the invariance assumption in research with a longitudinal design, as there might be differences between and within children that are captured distinctively by both designs. However, a cross-sectional invariance analysis is a good starting point in assessing the equivalence of the constructs.

Finally, we questioned which level of invariance may suffice for research addressing young children, as we know that the very nature of the accelerated and non-linear development challenges the invariance assumption. Kern and colleagues (2016) mentioned that the level of invariance will depend on the particular research questions and the nature of the data. We argue that achieving at least configural invariance may be a sensible compromise between the rigor of the statistical methodologies and the changing nature of the development of young children. For developmental research, configural invariance may suffice, as using the same factor structure across time points (or grades) allows the latent constructs to be modeled together. Furthermore, the lack of other levels of invariance encapsulates the developmental differences of the construct. For example, it might be that for a three-year-old child, the ability to walk in a line with the heels raised is an important indicator of motor skills, but the same indicator could be less important for a five-year-old child. In this sense, the lack of metric invariance reflects those developmental differences. By all means, a longitudinal analysis conducted within a non-fully invariant population should always be interpreted with caution and the specific non-invariant time points should be clearly stated. For multi-group comparisons (e.g., grades), achieving configural invariance may not suffice, because configural invariance does not allow for substantive quantitative group comparisons, as suggested by Gregorich (2006). In this case, metric invariance seems more appropriate, as it allows fair comparisons of variances and covariances (Gregorich, 2006).

There is still a long way to go in terms of measurement invariance for developmental research. Gregorich (2006) suggests that the lack of studies testing measurement invariance is possibly due to the lack of awareness in the scientific community. However, Thurstone already raised this issue in 1947—and based on *Google Scholar* this work has been cited 5,207 times to date—so it might not be an awareness problem after all. Perhaps it is more related to the difficulty of testing and achieving invariance, particularly in studies focusing on young children. According to Kern and colleagues (2016), the simple acknowledgment of the need for measurement invariance is an important step; however, in our view, raising awareness and acknowledging the importance of measurement invariance may not be sufficient. It seems imperative that the field moves forward and starts examining and reporting analyses of measurement invariance as a fundamental property of development research irrespective of whether these employ a cross-sectional or longitudinal design.

2.4.3 Limitations

This study arose from the need to test measurement invariance as a pre-requisite to continue with typical developmental statistical analyses. Therefore, the factor structure of the selected domains was restricted to the tests and measurements as used in the research project (considering time and monetary constraints), and by no means included a comprehensive application of different possible tests and tasks that could cover each of the three included domains. Even so, while the research project and the present study started from a substantive question rather than a methodological question, we strived for methodological robustness. A second limitation was the use of an accelerated longitudinal design. Even though this design is increasingly used in longitudinal research, it also added an extra level of complexity to the modeling of the factor structure of the three developmental domains, as the factor structure needed to be replicated not only across time points but also across imputed data sets, and the imputation process might have introduced extra variation. A third limitation was the sample size. For the cross-sectional analysis, our total sample had to be divided into three groups, leading to relatively small sample sizes. Having a larger sample may aid to adequately fit complex models and identify more appropriate solutions.

2.4.4 Recommendations and implications

A first recommendation is in the line of prevention. Although it may seem obvious, it is imperative for developmental researchers to have a deep understanding of the constructs to be studied and to conduct careful examination of the tasks or instruments that will be used—considering that they are developmentally sensitive and appropriate. According to Meredith and Horn (2001) achieving measurement invariance is largely about having a good research plan and design. For example, Petersen and colleagues (2016) suggested, among other valuable ideas, the use of different measures that are appropriate according to the developmental moment, and to use overlapping tests that serve as an anchor to connect the entire developmental span and to retain the comparability of the scores. In this way, balance can be carefully maintained between construct validity and comparability in longitudinal studies. This is a clear example of how a good design may help prevent and overcome measurement invariance. A second recommendation is the use of statistical techniques that do not assume measurement invariance. For example, the use of complex dynamic systems analyses, non-linear growth modelling, or even more traditional person-centered approaches are more flexible alternatives to portray different developmental stages of young children (Grimm, Ram, & Hamagami, 2011; Lanza & Cooper, 2016; Lewis, 2000). Finally, although exploring and hopefully achieving measurement invariance in longitudinal research would be ideal, we agree with Petersen and colleagues (2016) that in the search for the balance between statistical assumptions and capturing the changing nature of developing young children, priority must be given to the appropriate reflection of developmental characteristics of the children.

Chapter 3

THE ABC OF THE RELATIONS BETWEEN MOTOR SKILLS AND PRE-ACADEMIC SKILLS IN YOUNG CHILDREN: THE MEDIATOR ROLE OF EXECUTIVE FUNCTIONS

The ABC' of the Relations between Motor Skills and Pre-Academic Skills in Young Children: The Mediator Role of Executive Functions

Abstract

This study addresses the possible mediator role of executive function in the relation between motor skills and pre-academic skills in two groups of early childhood children: a younger group (age 3 to 5, n = 132) and an older group (age 4 to 6, n = 145). The results showed a full mediation of executive functions on the relation between motor skills and pre-academic skills in both groups. However, after controlling for baseline performance and relations, the full mediation persisted only in the younger group. Further discussion on the pivoting role of executive functions as the cognitive process that links motor skills and pre-academic skills in young children and the temporal dependency of such relation is provided.

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3.1 Introduction

Extensive research has documented the associations between motor and cognitive developmental domains (e.g., David, Pitchford, & Limback, 2011; Diamond, 2000; Kiefer, & Trumpp, 2012; Van der Fels, et al., 2015), as well as between cognitive and academic domains (e.g., Blair & Razza, 2007; Miller, Müller, Giesbrecht, Carpendale, & Kerns, 2013). However, research evidence is still indecisive regarding the nature and magnitude of the relation between motor and academic skills in young children. There is a set of cognitive processes that could explain the underlying relation between motor skills and academic skills, and why and how this relation works. Executive functions have shown to play an important role in our understanding of the motor-academic relation, due to the strong evidence connecting, on the one hand, motor skills and executive functions (e.g. Ahnert, Schneider, & Bos, 2009; Davis, Pitchford, & Limback, 2011; Livesey, Keen, Rouse, & White, 2006; Roebers et al., 2014), and on the other hand, executive functions and pre-academic skills (e.g. Lonigan, Lerner, Goodrich, Farrington, & Allan, 2016; Purpura, Schmit, & Ganley, 2017). However, further empirical exploration is needed on the relation between motor skills and academic skills in young children to help disentangle the complex motor-cognitive relation and to better direct further interventions. In the present study, we explore the role of executive functions on the relation between motor skills and pre-academic skills. Based on the previous evidence placing executive functions in a pivoting position—theoretically and empirically—between motor skills and pre-academic skills, we expect the mediation of executive functions to be full on the relation between motor skills and pre-academic skills. Furthermore, we focus on children in the early childhood years (from 3 to 6 years old), as the motor-cognitive relation may be stronger in this developmental period.

Hence, in the next section we first present the definition of the three constructs we study—motor skills, executive functions, and pre-academic skills—and their developmental characteristics during early childhood. Afterwards, we organize the literature review around the three paths that compose the mediation model: (A) the relation between motor skills and executive functions, (B) the relation between executive functions and pre-academic skills, and finally the possible relation between motor skills and pre-academic skills (C).

3.1.1 The rapid, multidimensional development in early childhood

Early childhood—particularly between ages 3 and 6—is not only a period of accelerated motor and cognitive development (Kuther, 2016), but it is also a stage when children are expected to develop a series of pre-academic skills that will become the foundation of later school performance (Duncan et al., 2007).

Motor development refers to the process of acquisition of movement patterns and skills (Malina, 2003). The motor development of young children is concentrated around mastering the fundamental motor skills, which include locomotor skills, manipulative skills—projection and reception— and balance skills (Logan et al., 2018; Malina, 2003). These fundamental motor skills are the foundation of more sophisticated and distinct motor skills and are important for participation in physical activity and execution of daily life activities (Logan et al., 2018). Typically developing children master the fundamental motor skills at about 6 to 8 years of age (Piek, Hands, & Licari, 2012; Sugden, Wade, & Hart, 2013). There is, additionally, a general distinction between gross and fine motor skills. Gross motor skills comprise the large muscles and refer to balance, orientation, and the movement of trunk and limbs—e.g., jumping, walking, throwing; fine motor skills require the coordination of small muscles, involve fine motor precision and integration, and refer to tasks like drawing, writing, and speaking (Cameron, Cottone, Murrah, & Grissmer, 2016; Van der Fels et al., 2015).

Executive functions (EF) are “higher order, self-regulatory, cognitive processes that aid in the monitoring and control of thought and action” (Carlson, 2005, p. 595). In adults, there is a general agreement on the existence of three core EF: working memory refers to the ability to monitor and revise information; inhibitory control refers to the ability to suppress pre-potent responses; and shifting refers to the ability to switch between multiple tasks (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). However, in models of EF in young children—between 3 and 6 years—only inhibitory control and working memory are clearly distinguishable (Lerner & Lonigan, 2014; Miller et al., 2012), and build the foundation for the later development of shifting (Best & Miller, 2010; Garon, Bryson, & Smith, 2008; Senn, Epsy, & Kaufman, 2004). Therefore, in this study, we focus on working memory and inhibitory control to depict EF in young children.

Finally, pre-academic skills are typically depicted in terms of early numeracy and early literacy. Early literacy refers to the acquisition of the skills, knowledge and attitude pillars for reading and writing (Whitehurst & Lonigan, 1998). Storch and Loningan (2002) refer to early literacy in terms of code-related skills—including among others, knowledge of graphemes, grapheme-phoneme correspondence and phonological awareness—and oral language skills—including semantic, syntactic and conceptual knowledge. Early numeracy is expressed by three general domains: numbering—including among others the knowledge of verbal counting, counting principles and cardinality, numerical relations and arithmetic operations (Purpura, Hume, Sims, & Lonigan, 2011). Early numeracy and early literacy develop rapidly during the early childhood years and are mutually interrelated on initial status and growth rate (Toll & Van Luit, 2014).

3.1.2 The relation of motor skills and executive functions (A)

The relation between motor and cognitive skills has given rise to the notion of embodied cognition, which posits that the interactions of the body with the external context are the roots of cognitive processes, in this sense, having sufficient and appropriate sensory-motor experiences are indispensable for human cognition to develop (Keifer & Trumpp, 2012; Wilson, 2002). This notion draws on the Piagetian developmental stages, where it was recognized that sensoriomotor experiences are important for the emergence of cognitive abilities (Piaget & Inhelder, 1996). Recent research has argued that the development of motor and cognitive functions is even more closely related than previously suggested (Davis, Pitchford, & Limback, 2011). For example, from an anatomical perspective, motor and cognitive functions are coupled using the same brain structures, as both are mediated by the co-activation of the cerebellum—important for complex and coordinated movements—and the prefrontal cortex—critical for higher-order cognitive functioning (i.e., executive functioning; Diamond, 2000). Furthermore, longitudinal evidence with children aged 4 to 11 shows that cognitive and motor skills are consistently and moderately correlated across this age range, and that their developmental trajectories are similar (Davis, Pitchford, & Limback, 2011). In the efforts to untangle the motor-cognitive relation, executive functions have been proposed as the "common domain-general factor underlying the motor-cognitive performance link" (Roebers et al., 2014, p. 294). Additionally, it has been hypothesized that there is a similar developmental timing of motor skills and executive functions, which presents an important acceleration in the period from 3 to 6 years old (Ahnert, Schneider, & Bos, 2009; Livesey, Keen, Rouse, & White, 2006).

The relation between motor skills and executive functions has been studied concurrently and longitudinally, yielding different results. The cross-sectional study of Houwen, van der Veer, Visser and Cantell (2017) including 153 children between 3 and 5 years old, reported weak to moderate relations between a general motor skills composite and different subscales of a parent-based executive functions inventory. However, after controlling for socioeconomic status, age, gender and attention deficit hyperactivity disorder diagnosis, only the subscale of working memory remained significantly associated with motor skills (β = 0.20). In another study including 156 6-year-olds a positive strong relation between executive functions and motor skills was reported, with a slightly stronger relation for gross motor skills (r = .75) than for fine motor skills (r = .67; Oberer, Gashaj & Roebers, 2017). In the longitudinal study conducted by Roebers and colleagues (2014) fine motor skills and executive functions were significantly and positively correlated (r = .60) only in the first assessment with 5-year-olds; neither longitudinal nor cross-sectional associations between fine motor skills and executive functions were significant in the assessment of the same children at the age of 6. In a similar vein, in a study with 112 7-year-old children, only a few and weak correlations were found between executive functions and motor control: cognitive flexibility showed weak negative relations with the jumping task (r = -.26), and working memory was weakly related to postural flexibility (r = .29; Roebers & Kauer, 2009). In another longitudinal study including 92 young children (3 to 5 years old), children's visual-motor integration had a significant modest association with executive functions five months later (β = .27). However, this relation became non-significant after controlling for the previous performance of executive functions (MacDonald et al., 2016). Finally, Piek, Dawson, Smith, and Gasson (2008) in their longitudinal study reported that gross motor trajectories of children assessed from 4 to 48 months were a significant predictor of children's working memory and processing speed in their school years (6 to 11 years old). In the same study, fine motor skills did not significantly predict any cognitive outcome.

Seemingly, the relation between motor skills and executive functions in young children is strongly dependent on the components that are assessed and the age span of the participants. Furthermore, as highlighted by Davids, Pitchford, and Limback (2011), the nature of the relation between motor and cognitive skills possibly changes with age, as the different skills may develop at different rates. Consequently, grouping children in broad age categories, like the early childhood period—between 3 and 6 years old—or school aged children—from 7 to 12 years old—may be masking important age differences.

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3.1.3 The relation of executive functions and pre-academic skills (B)

Several studies addressing young children—aged 3 to 6—have reported different patterns of the relation between executive functions and pre-academic skills. For example, in their cross-sectional study, Miller and colleagues (2013) found that working memory significantly contributed to literacy (β = .80) and math skills (β = .77), however, no significant relations were found with inhibitory control. In contrast, Blair and Razza (2007) showed that inhibitory control in 6-year-old children presents positive significant relations with math (β = .20) and reading ability—phonemic awareness (β = .27), and letter knowledge (β = .17)—but no significant relations were found with attention shifting. Furthermore, in the study of Lonigan, Lerner, Goodrich, Farrington and Allan (2016) with 154 Spanish-speaking young children (mean age 4.5 years old), it was reported that both inhibitory control and working memory substantially correlated with numerous early literacy skills, with *r*'s ranging from .17 to .58 and from .28 to .65, respectively. Finally, Purpura, Schmitt, and Ganley (2017) supported the idea that more complex executive functions are related to more advanced academic abilities, as shown in their study of 125 young children (3 to 5 years old). They concluded that inhibitory control was broadly related to more general pre-academic skills—moderately related to early numeracy and weakly related to literacy; while working memory was a predictor of only the more complex aspects of early numeracy—like comparison and combination of numbers, and literacy—like phonological awareness.

The relation between executive functions and pre-academic skills has been reported not only concurrently but also longitudinally. In the study of Carlson (2013) executive functions assessed at the beginning of kindergarten predicted growth on math and reading achievement through middle school. Executive functions assessed at 5.4 years old—based on an inhibitory task—showed a positive concurrent relation with all academic tasks assessed at the beginning of kindergarten (six tests covering early literacy and numeracy), but only a couple remained significant on the following assessment 5 months later (applied problems and sound awareness), after controlling for previous performance (Cameron et al, 2012). In another longitudinal study including 562 children assessed at 4.5, 5 and 6 years old, it was reported that when addressed as general constructs, executive functions and pre-academic skills showed a bidirectional positive relation in the pre-kindergarten year (from 4.5 to 5 years old), but only a uni-directional relation from EF to pre-academic skills in the kindergarten year (from 5 to 6 years old). Additionally they explored the relation between a general construct of executive functions with specific domains of pre-academic skills, and showed that in pre-kindergarten a significant bidirectional positive relation remained between executive functions and early numeracy tasks, whereas only a marginal relation between executive functions and early literacy tasks was found (Fuhs, Nesbitt, Farran, & Dong, 2014). Finally, in a series of studies with 175 Italian children, researchers reported that a composite of working memory and shifting assessed at age 5, significantly positively predicted mathematic performance at ages 6 (β = .60) and 8 (β = .89), and was a strong predictor of reading comprehension at age 8 (β = .68). Inhibitory control did not show significant relations, neither with mathematic nor with literacy performance (De Franchis, Usai, Viterbori, & Traverso, 2017; Viterbori, Usai, Traverso, & De Franchis, 2015).

3.1.4 The relation of motor skills and pre-academic skills (C)

The relation between motor skills and academic skills in children has gained attention in the last decades, however, the mechanisms that explain this relation in young children are still unclear. There are two lines of thought to possibly explain this relation: a direct path—considering diverse components of motor skills—and an indirect path—having as mediator executive functions.

Regarding a possible direct path, the main discrepancies in the body of evidence on the relation between motor skills and pre-academic skills seem to be related to the distinction between fine and gross motor skills. For example, in a nation-wide longitudinal study including 12,583 children, Son and Meisels (2006) reported significant concurrent and longitudinal relations between motor skills assessed at 5.5 years old and academic skills assessed at 7 years old. In this study a stronger positive significant relation was found between visuomotor skills and academic skills—mathematics β = .20 and reading β =.17—than between gross motor skills and academic skills—mathematics β = .06, and reading β = .06. Moreover, Grissmer, Grimm, Aiyer, Murrah and Steele (2010) analyzed three longitudinal studies conducted in young children (the Early Childhood Longitudinal Survey-Kindergarten Cohort, ECLS-K; the British Birth Cohort Study, BCS; and the National Longitudinal Survey of Youth, NLSY) and reported a consistent positive significant effect of fine motor skills on later reading (β's ranging from .07 to .26) and math achievement (β's ranging from .05 to .36) after controlling for previous reading and math performance, socioemotional variables and family and home characteristics. Gross motor skills did not show any significant relation with math or reading achievement.

Other studies have addressed the direct relations between motor skills and pre-academic skills as well, but also accounting for the influence of executive functions. For example, in a study conducted with children from 4 to 6 years old, a significant positive relation was found between visuomotor skills and executive functions with academic success, holding different effects for emergent literacy, math and vocabulary. Visuomotor skills were positively related to math and emergent literacy, whereas executive function was positively related to emergent literacy and vocabulary (Becker, Miao, Duncan, & McClelland, 2014). Different results were obtained in another study including children from 6 and 7 years old. This study reported that better fine motor skills at the end of kindergarten (6 years old) significantly predicted academic achievement ($\beta = 0.58$) at the end of first grade (7 years old), after controlling for intelligence. However, the relations dropped in statistical significance after the inclusion of executive functions (Roebers et al., 2014), which suggests a possible mediation effect of executive functions. In the longitudinal study of Cameron and colleagues (2012) fine motor skills—specifically design copy—assessed at the entry of kindergarten (mean age 5 years old) showed unique contributions to three literacy tasks—letter word identification, passage comprehension and sound awareness—tested four and nine months later, even when executive functions were included. In the same study, gross motor skills did not significantly predict any of the academic tests in the subsequent assessments.

These results suggest that the direct relation between motor skills and academic skills depends on the different motor components, and on the presence or absence of executive functions (or other cognitive processes). Therefore the second possible path is via the mediation effect of executive functions. As previously discussed, there is a large amount of scientific evidence that connects executive functions with academic skills, both concurrently and longitudinally. The strength of this relation, next to the connection between motor skills and executive functions, suggests a pivotal role of executive functions potentially mediating—fully or partially—the relation between motor skills and pre-academic skills. Though theoretically the mediating role of executive functions is substantiated, more empirical evidence is needed to test this relation. To our knowledge, only one longitudinal study including older children (10 to 12 years old) tested and found a full mediating role of executive functions, in the relation between motor skills and academic achievement, reporting a significant positive indirect effect of $\beta = 0.30$ (Schmidt et al., 2017).

3.1.5 Aims, expectations and research questions

This study aims to explore the relation between motor skills and pre-academic skills in young children, and the possible mediator role of executive functions. Based on the strong—theoretical and empirical—relations reported between executive functions and motor skills, and between executive functions and pre-academic skills, we test a model where executive functions work as a pivot that connects motor skills and pre-academic skills. We argue that a full mediation is highly probable, but the question about the existence of a direct effect between motor skills and pre-academic skills, with and without executive functions included, remains open. Additionally, to further clarify the relation between the three domains in young children, we also include their concurrent relations at the baseline. Furthermore, we test the proposed model in two different age groups, namely a younger cohort—age 3.5 to 5— and an older cohort—age 4.5 to 6.

Our research questions are:

1. Is there a relation between motor skills and pre-academic skills in young children?

2. Is this relation mediated—partially or fully—by executive functions?

3. Are the relations explored in questions 1 and 2 equally attested in younger as in older children?

3.2 Method

3.2.1 Research context and design

This study is part of a larger research project (Study of the Integral Development of Preschool children, *Estudio del Desarrollo Integral del Preescolar* - EDIP) that addressed the development of Mexican young children in multiple domains, between ages 3 and 6. Some features presented as research context, design, procedure and participants are equivalent among this and other sub-studies. This project took place in Mexico City, Mexico. Early childhood education (ECE) in Mexico is obligatory starting at age 3. Children are expected to complete three years of ECE before starting primary education: ECE 1 (3 to 4 years old), ECE 2 (4 to 5 years old) and ECE 3 (5 to 6 years old). Public ECE centers are under the responsibility of the government and cover most of the ECE in the country (Yoshikawa et al., 2007). For this study, we focused on the general public ECE centers (*jardín de niños*) as they serve the largest number of young children in Mexico. In collaboration with the Preschool Sectorial Directorate from the Ministry of Education, five public ECE centers from the urban area of Mexico City were recruited to participate. Sixty children per center were invited to participate, 300 in total. As the focus was on typically developing children, those identified by the Special Needs Education Unit (UDEEI) were not considered for participation. A longitudinal assessment was planned including four measurement occasions: January 2016, June 2016, January 2017 and June 2017. Children who were enrolled in the study during ECE 1 (cohort 1), were assessed at halfway and end of ECE 1, and at halfway and end of ECE 2. Children who were in ECE 2 at the start of the study (cohort 2), were assessed at halfway and end of ECE 2, and at halfway and end of the ECE 3.

3.2.2 Procedure

Parents or guardians of the children gave written consent for their children to participate. Ethical approval for this study was granted by the Ethics Committee of Pedagogical and Educational Sciences of the University of Groningen. For the evaluation of the children, six assessors were recruited and trained before the testing period. Assessors were all Mexican, graduate psychologists or psychology students with sufficient mastery of the testing procedures as demonstrated in practice sessions. Children were assessed individually and in a group-session. The complete testing battery—including the executive functions and pre-academic skills tests—was divided into two one-on-one sessions of approximately 15 to 20 minutes each conducted on separate days, and a 20-minute group session to test motor skills. The two individual sessions were conducted in a separate testing room (e.g., the school library) in pull-out sessions during regular school hours. The group session was conducted at the school's gym or music room, where a circuit of the motor tasks was set to evaluate several children simultaneously. Additionally, children were measured and weighted at the beginning of the assessment.

3.2.3 Participants

The final sample for this study consists of 277 children: 132 form the younger cohort and 145 from the older cohort (see section on missing data). Table 3.1 provides an overview of the final sample characteristics and specific sample size per measurement occasion. Body mass index (BMI) was calculated using kg/m2, children were classified as underweight, normal weight or overweight or obese, using the classification of the international child growth standards of the World Health Organization adjusted by age and sex (WHO, 2007).

Table 3.1 *Demographic characteristics of the sample*

	Younger cohort *n* = 132	Older cohort *n* = 145
Sex (% female)	60.6	54.5
Mother educational level (%)		
Pre-primary education	0	0.7
Primary education	14.1	12.1
Lower secondary education	39.8	30.7
Upper secondary education	26.6	37.1
Bachelor degree, specialization or master degree	19.5	19.3
Monthly income (%)		
Range 1-2 (1st decile)	67.2	61.2
Range 3-4 (2nd decile)	12.5	23.7
Range 5-6 (3rd decile)	12.5	9.4
Range 7-8 (4th decile)	4.7	0.7
Range 9 (5th decile or higher)	3.1	5.0
Body Mass Index[a] M(%)		
Severe underweight	0	11.91(2.2)
Underweight	13.74(9.4)	13.47(11.5)
Normal	15.58(67.7)	15.33(70.5)
Overweight	17.46(20.5)	17.20(10.8)
Obesity	19.66(2.4)	20.7(5.0)
Sample *n* (Age in months M)		
Measurement occasion 1	127 (43.7)	139 (55.6)
Measurement occasion 2	127 (47.4)	140 (59.3)
Measurement occasion 3	98 (54.9)	115 (66.7)
Measurement occasion 4	103 (59.5)	121 (71.2)

Note. [a] BMI based on measurement occasion 1.

Two indicators were used to explore the sociodemographic characteristics: mother educational level and the monthly household income. Mother educational level was based on the International Standard Classification of Education (ISCED) of UNESCO. Household monthly income was assessed using Mexico’s 2012 household income deciles (INEGI, 2012). As the study includes public ECE centers in low socioeconomic areas, nine ranges of household income were created based on the five lower deciles. About 64% of our sample reported a monthly household income corresponding to the first lower decile of the average household income of the country (less than 7,000 Mexican pesos, about 375 USD). No significant differences were found in the sociodemographic characteristics or the BMI classification between cohorts: mother educational level, χ^2 (5) = 4.96 p = .42, monthly income, χ^2 (8) = 12.11 p = .14, and BMI, χ^2 (4) = 8.38 p = .08.

3.2.4 Instruments

Executive functions. We included tasks of inhibitory control and working memory from the Neuropsychological Battery for Preschoolers (*Batería neuropsicológica para preescolares*, BANPE; Ostrosky, Lozano, & González-Osornio, 2016). For inhibitory control we used two tasks: day-night and angel-devil. In the day-night task the child was presented with two cards, one depicting the sun and one depicting the moon. The child was asked to say “day” when a moon-card was shown and “night” when a sun-card was presented. The score represents the amount of correct trials out of 16. For the angel-devil task the child was asked to follow the instructions given by the angel but ignore the instructions given by the devil. The score represents the performance on the devil trials, with a maximum of 12 points.

For working memory, we used digits backward and blocks backward. Digits backward is a verbal task where the child was asked to repeat series of numbers that the assessor mentioned in inverse order, starting with a series of two digits up to a maximum of six digits. The score represents the maximum length achieved (e.g., three digits successfully repeated in the inverse order corresponds to a score of 3). The maximum score is 6. Blocks backward is a visuospatial task in which children were presented with a panel of 3x3cm wooden blocks distributed horizontally on a plank, and were asked to point in the inverse order the blocks that the assessor had previously pointed out. The assessor started with a series of two blocks up to a maximum of six blocks. The score represents the amount of successfully inverse-pointed blocks, with a maximum score of 6.

Motor skills. We used the Movement Assessment Battery for Children-2 (MABC-2; Henderson, Sugden, & Barnet, 2007) which assesses fundamental motor skills. We utilized the age band 1—appropriate for children between 3 and 6 years—consisting of eight tasks divided in three theoretical components: manual dexterity (posting coins, threading beads and drawing trial) aiming and catching (throwing and catching a bean bag), and balance (one-leg balance, walking with heels raised, and jumping on mats).

For posting coins, children are asked to place coins into a bank box as fast as they can. The final score is the average time in seconds of the best performance of each hand. In threading beads, children are asked to thread plastic beads into a lace as fast as they can. The score represents the fastest performance in seconds. For the drawing trial, children have to follow a basic labyrinth without going out of the borders. The score represents the number of errors. For these three tasks the final scores were reverse coded. For the throwing task, children were asked to throw a beanbag onto a mat that was placed 1.8 meters away from them. The score represents the amount of successful throws out of 10. For the catching task, children were asked to catch a beanbag that was thrown to them from a distance of 1.8 meters. The score represents the amount of successful catches out of 10. In the one-leg balance task, children were asked to keep the equilibrium while standing on one leg. The score represents the average of the best performance achieved for each leg. All tasks had a practice trial before the definitive assessment.

Within this age band, some tasks have two distinctive versions based on age: 3- and 4-year-olds and 5- and 6-year-olds. The versions vary in amount of stimuli received (posting coins and threading beads) or in the scoring rule (catching beanbag and jumping on mats). To ensure comparability, we performed an age-correction of the scores by calculating regression lines of the standardized performance by age in months and adding or subtracting the difference in the intercept coefficients at 60 months (age of the change of version) of version A and B on the standardized performance.

Pre-academic skills. We assessed pre-academic skills utilizing two tests of early numeracy and two tests of early literacy. For early numeracy we used the tests of applied problems and quantitative concepts (form A) of the Woodcock-Johnson Battery III, Achievement tests, Spanish-form (WJ III Pruebas de aprovechamiento; Muñoz-Sandoval, Woodcock, McGrew, & Mather, 2005). In applied problems, children were asked to recognize quantities and solve basic numerical problems. In quantitative concepts, children were confronted with numerical concepts as big-small, counting, identification of numbers and mathematical vocabulary and symbols. For early literacy we applied two subtests of the Woodcock-Muñoz Language Survey Revised, Spanish Form (WMLS-R; Woodcock, Muñoz-Sandoval, Ruef, & Alvarado, 2005): Letter-word identification and picture vocabulary. In letter-word identification, children had to recognize the graphical representation of letters and words and fluently read basic words. In picture vocabulary, children were asked to name a series of images of objects.

The score in these tasks represents the number of correct answers. Internal consistency was based on the first measurement occasion including the three years of ECE, and Cronbach's alphas were calculated for the four subtests utilized. All tests showed an acceptable alpha value: Picture vocabulary (α = .91), Letter-word identification (α = .95), Applied problems (α = .89) and Quantitative concepts (α = .77).

3.2.5 Missing data

The intended sample was of 300 children. We had an initial non-response of 7% (21 children) leading to a sample of 279 children. Additionally, two children from the younger cohort were not included because they were only tested on measurement occasion 2, which is not used in this study. Therefore the final sample for this study is 132 children form the younger cohort 1 and 145 children form the older cohort, a total of 277 children. A missing value analysis revealed that Little's Missing Completely at Random (MCAR) test was not significant in both cohorts—younger cohort χ^2 (291) = 319.94, p = .11, older cohort χ^2 (253) = 263.89, p = .30. About 70% of the children completed all four measurement occasions (n = 194), 14.33% completed three assessments (n = 40), 13.97% completed two assessments (n = 39), and 2.15% (n = 6) only one assessment. On variable level the proportion of missing information ranged from 4.1% to 26.9%; the exact proportions of missings per variable are given in Table 3.2 in the results section. Missing data was handled by means of Full Information Maximum Likelihood using Mplus.

3.2.6 Analytical strategy

The two cohorts were analyzed separately using Mplus version 7.3 (Muthén & Muthén, 2015). As preparatory analyses, we conducted a factor analysis on the three constructs to identify the model that best suits the data: motor skills at measurement occasion 1, executive functions at measurement occasion 3 and pre-academic skills at measurement occasion 4. Three models were tested for motor skills: one with a general single factor, one including a distinction between fine and gross motor skills, and one including the proposed structure of the movement ABC—manual dexterity, aiming and catching and balance—(Henderson, Sugden, & Barnet, 2007). Two models were tested for executive functions: one of a general single factor, and one including a distinction between inhibitory control and working memory. Finally, two models were tested for pre-academic skills: one of a general single factor and one including a distinction between pre-numeracy and pre-literacy.

For testing the mediation effect of executive functions on the relation between motor skills and pre-academic skills a series of models were tested. First, a model including only the direct relation between motor skills at measurement occasion 1 and pre-academic skills at measurement occasion 4 was performed for the younger and older cohort separately. Afterward, executive functions—assessed at measurement occasion 3—were included as a mediator between motor skills and pre-academic skills (referred to as mediation model 1). Finally, to account for initial performance and baseline relations, executive functions and pre-academic skills at measurement occasion 1 were added to the mediation model (referred to as mediation model 2). For this purpose, a composite score was created for executive functions and pre-academic skills by parceling the corresponding tasks at measurement occasion 1.

Model fit was assessed by means of Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI) and Standardized Root Mean Square Residual (SRMR). Additionally, χ^2 is reported for informational purposes. The general recommended cut-off values of these fit indices are: for RMSEA and SRMR a value < .05 for good fitting models and < .08 for acceptable models, and CFI > .90 for acceptable models and > .95 for good fitting models.

3.3 Results

Table 3.2 presents the descriptive statistics of the tasks included in the model: motor skills at measurement occasion 1, executive functions at measurement occasions 1 and 3, and pre-academic skills at measurement occasion 1 and 4.

3.3.1 Preparatory analyses

The results of the diverse models tested to explore the latent construct of motor skills, executive functions, and pre-academic skills in both cohorts—younger cohort and older cohort—are summarized in Table 3.3. Gray-marked cells represent the best fitting model. For motor skills the single-factor model was the best fitting model for both groups. In the younger cohort the task ‘catching’ had a non-significant factor loading; in the older cohort the tasks ‘jumping on a mat’ and ‘throwing’ were non-significant. In the older cohort the model fit with a single factor was marginally acceptable, and although a model deleting the non-significant indicators improved

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Table 3.2 *Descriptive statistics per measurement occasion by cohort*

Task[a]	Younger cohort			Older cohort		
	Range	Mean (*SD*)	% Miss	Range	Mean(*SD*)	% Miss
Pre-academic skills						
Picture vocabulary M1	6-30	16.86(4.37)	6.7	6-35	22.34(5.05)	4.1
Picture vocabulary M4	13-36	23.94(5.22)	23.1	18-41	30.85(5.11)	19.3
Letter-word M1	0-13	4.81(1.95)	6.7	3-36	7.99(4.11)	5.5
Letter-word M4	4-38	8.40(4.57)	23.1	4-44	18.50(8.20)	19.3
Applied problems M1	2-15	7.34(2.91)	8.2	5-24	12.54(3.64)	6.2
Applied problems M4	5-24	12.91(3.79)	22.4	11-28	18.92(3.82)	18.6
Quantitative concepts M1	0-8	4.94(1.77)	8.2	1-13	7.57(2.15)	6.2
Quantitative concepts M4	4-15	7.69(1.82)	22.4	5-29	10.39(2.70)	18.6
Executive functions						
Digits backward M1	0-12	.05(.31)	8.2	0-3	.57(.93)	6.2
Digits backward M3	0-3	.56(.95)	26.9	0-5	1.41(1.21)	20.7
Angel-devil M1	0-12	2.98(4.15)	8.2	0-12	8.46(4.78)	6.2
Angel-devil M3	0-12	7.31(5.21)	26.9	0-12	11.35(2.23)	20.7
Blocks backward M1	0-3	.45(.90)	7.5	0-4	1.36(1.26)	4.1
Blocks backward M3	0-3	1.31(1.25)	26.9	0-5	2.27(1.27)	20.7
Day-night M1	0-16	9.28(4.96)	7.5	0-16	11.95(4.47)	4.1
Day-night M3	0-16	11.00(4.53)	26.9	1-16	13.48(3.04)	20.7
Motor skills						
Catching M1	0-9	5.21(2.29)	14.2	0-10	6.89(1.86)	8.3
Throwing M1	0-9	1.97(1.57)	15.7	0-9	3.55(2.25)	8.3
Balance one leg M1	.50-18.5	5.11(3.65)	14.2	1.5-30	10.54(7.15)	8.3
Walking heels raised M1	0-15	11.31(4.04)	14.2	2-15	13.69(2.25)	8.3
Jumping on mats M1	0-5	4.41(1.17)	14.2	0-5	4.81(.62)	8.3
Posting coins M1	7.5-21.5	13.69(2.76)	20.9	6.5-33.5	12.27(4.60)	9.7
Threading beads M1	21-125	48.46(16.64)	14.9	13-101	35.76(14.23)	9.0
Drawing trial M1	0-27	6.65(4.67)	15.7	0-10	2.35(2.33)	8.3

Note: [a] Based on raw scores, M1=Measurement occasion 1, M3= Measurement occasion 3, M4 = Measurement occasion 4. *SD*= Standard deviation, % Miss = Percentage of missing information.

model fit greatly— χ^2 (9) = 8.82, p = .45, RMSEA = .00, CFI = 1.00, SRMR = .04—we decided to keep the models including all the indicators following the recommendations of Goodboy and Kline (2017). For executive functions and pre-academic skills a single-factor model was preferred for both cohorts.

3.3.2 Relation between motor skills and pre-academic skills

A model testing the direct relation between motor skills and pre-academic skills without the presence of executive functions showed a positive significant relation for the younger cohort (β = .40, p = .01; χ^2 (53) = 67.93, p = .08, RMSEA = .04, CFI = .92, SRMR = .07) and for the older cohort (β = .62, p < .001; χ^2 (53) = 61.10, p = .20, RMSEA = .03, CFI = .94, SRMR = .06).

3.3.3 Mediation Analysis

Figure 3.1 presents the results of the mediation model 1 for both cohorts. There was no significant direct relation between motor skills and pre-academic skills after the inclusion of executive functions. A full mediation effect was found of executive functions on the relation between motor skills and pre-academic skills in the younger cohort (indirect effect: β = .39, p = .003) and in the older cohort (indirect effect: β = .40, p = .03). The mediation model 2, including baseline performance and relations of executive functions and pre-academic skills, is presented in Figure 3.2. A full mediation effect of executive functions on the relation between motor skills and pre-academic skills remained in the younger cohort (indirect effect: β = .33, p = .003). However, the indirect effect was non-significant in the older cohort (β = .29, p = .10) after controlling for baseline performance and baseline relations. The factor loadings of the indicators of each domain on this final model are presented in Table 3.4.

Table 3.3 *Tested models of factor structure per cohort*

Cohort	Construct	Model	χ^2	*df*	*p*	RMSEA	CFI	SRMR	$\Delta\chi^2$	Δdf	*p*
Younger cohort	Motor skills M1	Single model	23.21	20	.27	.04	.97	.05			
		Two factors: gross and fine motor skills [a]	22.45	19	.26	.04	.96	.05	.76	1	.38
		Three factors: manual dexterity, aiming and catching, and balance [b]	21.39	17	.20	.05	.95	.05	1.82	3	.61
	Executive functions M3	Single model	2.70	2	.25	.06	.98	.03			
		Two factors: inhibitory control and working memory	2.70	1	.10	.13	.97	.03	.00	1	1.00
	Pre-academic skills M4	Single model	2.45	2	.29	.05	.99	.03			
		Two factors: early numeracy and early literacy	2.29	1	.12	.11	.98	.03	.16	1	.68
Older cohort	Motor skills M1	Single model	25.75	20	.17	.05	.86	.06			
		Two factors: gross and fine motor skills [c]	25.71	19	.13	.05	.83	.06	.04	1	.84
		Three factors: manual dexterity, aiming and catching, and balance [b, d]	21.52	17	.20	.05	.89	.05	4.23	3	.23
	Executive functions M3	Single model	.09	2	.95	.00	1.00	.01			
		Two factors: inhibitory control and working memory [d]	.02	1	.88	.00	1.00	.00	.07	1	.79
	Pre-academic skills M4	Single model	3.75	2	.15	.09	.97	.03			
		Two factors: early numeracy and early literacy [d]	1.10	1	.29	.03	.99	.02	2.65	1	.10

Note. M1 = measurement occasion 1, M3 = measurement occasion 3, M4 = measurement occasion 4, *df* = degrees of freedom. [a] Correlation between factors $r = .90$, [b] Factor 'aiming and catching' none significant loadings, [c] Correlation between factors $r = .94$, . [d] Correlation between factors $r > 1$. Best performing model is marked with gray shading.

3

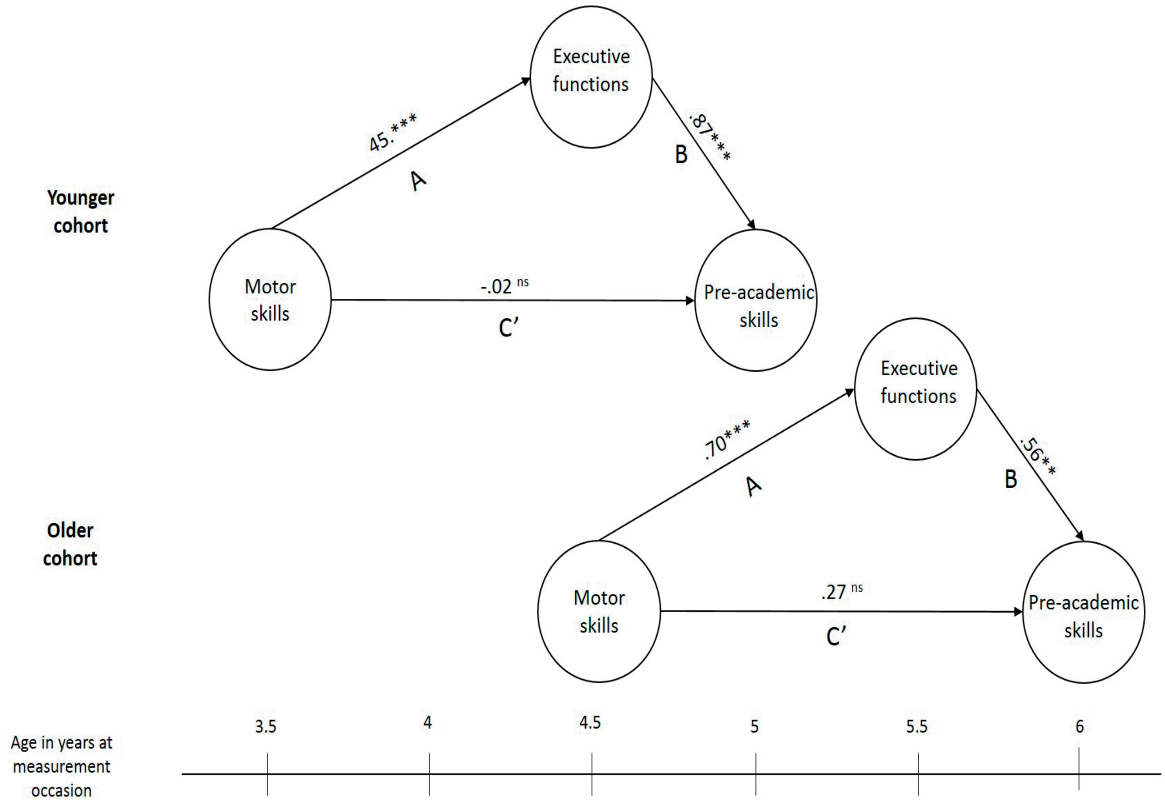

Figure 3.1. Mediation model 1. Younger cohort χ^2 (101) = 112.69, *p* = .20, RMSEA = .03, CFI = .96, SRMR = .07. Older cohort χ^2 (101) = 105.21, *p* = .36, RMSEA = .01, CFI = .98, SRMR = .06. ns = non-significant, ****p* < .001, ***p* < .01, **p* < .05.

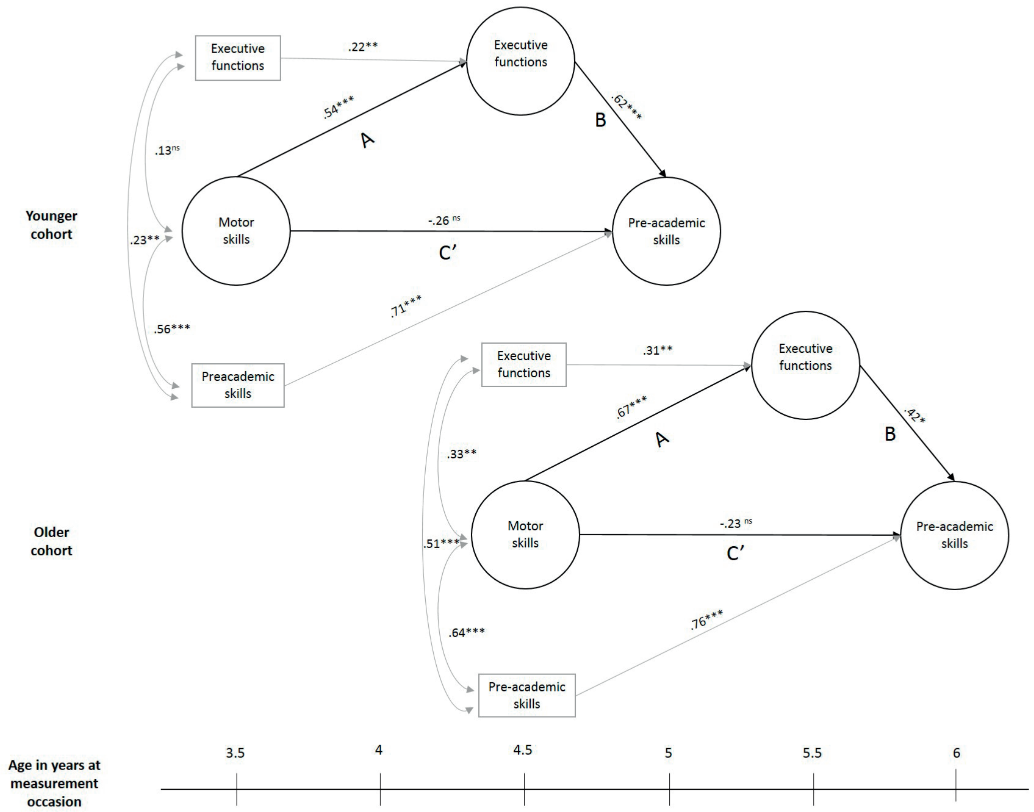

Figure 3.2. Mediation model 2 (including baseline performance and baseline relations). Younger cohort $\chi^2(129) = 164.72$ $p = .01$, RMSEA = .04, CFI = .91, SRMR = .09. Older cohort $\chi^2(129) = 152.44$ $p = .07$, RMSEA = .03, CFI = .93, SRMR = .06. ns= non-significant, $^{***}p < .001$, $^{**}p < .01$, $^{*}p < .05$.

Table 3.4 *Final measurement models per construct and cohort*

Construct	Task	Younger cohort		Older cohort	
		Factor loading[a]	Standard error	Factor loading[a]	Standard error
Motor skills	Catching	.13	.11	.28	.10
	Throwing	.42	.09	.17	.11
	Balance one leg	.37	.10	.42	.10
	Walking with heels raised	.64	.07	.36	.10
	Jumping on mats	.32	.10	.25	.10
	Posting coins	.56	.08	.28	.10
	Threading beads	.48	.09	.45	.10
	Drawing trial	.68	.07	.47	.09
Executive functions	Digits backward	.76	.07	.76	.07
	Angel-devil	.59	.08	.26	.10
	Blocks backward	.65	.08	.64	.07
	Day-night	.46	.10	.40	.09
Pre-academic skills	Picture vocabulary	.67	.06	.63	.07
	Letter-word identification	.45	.09	.70	.06
	Applied problems	.79	.06	.57	.07
	Quantitative concepts	.49	.08	.70	.06

Note. [a] Based on the mediation model 2, standardized solution. All factor loadings are significant at level $p < .05$, except for those marked in bold, which are non-significant.

3.4 Discussion

Our study explored the relations between motor skills and pre-academic skills in young children (aged 3 to 6), both directly and indirectly—i.e., via the mediation of executive functions. Although in traditional mediation analysis a direct path is expected to occur, in our study we questioned whether a direct relation between motor skills and pre-academic skills existed, and if so, whether this relation will be purely due to the effect of executive functions. Since we expected that the rapid development of children at this age could play a role in the relations explored, we tested this mediation model separately on two cohorts of young children—a younger cohort, with ages ranging from 3.5 to 5 years old, and an older cohort, with ages ranging from 4.5 to 6 years old. Our results showed two different facets of the relation between motor skills and pre-academic skills: without the influence of executive functions—namely a total effect—and with the mediation influence of executive functions—namely a direct and indirect effect.

Regarding the total effect, we observed positive significant relations between motor skills and pre-academic skills, which is in line with the previously reported studies (for example, Roebers et al., 2014, and Son & Meisels, 2006). Furthermore, after the inclusion of executive functions, we did not find a significant direct effect of motor skills on pre-academic skills in the younger cohort and the older cohort—which is aligned with our expectations. Our results support the notion that the relation between motor skills and pre-academic skills in young children is based purely on their common relation with executive functions, which was confirmed in our first mediation analysis (mediation model 1). This could be a reflection that the 'true' connection between motor skills and pre-academic skills is via higher-order cognitive processes, like executive functions. As proposed previously by Roebers and colleagues (2014), executive functions are a common general domain that underlies the motor-cognitive linkage. Additionally, the full mediating role of executive functions was also reported in the study conducted by Schmidt and colleagues (2017) in 10- to 12-year-olds. Moreover, our results showed a stronger indirect effect in both cohorts ($\beta = .39$ and $\beta = .40$) than the one reported by Schmidt and colleagues (2017; $\beta = .30$). This may be related to the age of the children, as in young children the developmental domains are highly intertwined (Snow & van Hemel, 2008) and therefore the motor-cognitive relations may be enlarged in this period.

However, when the initial performance of executive functions and pre-academic skills was accounted for, and the relations at the baseline level were included (mediation model 2), the full mediation effect of executive functions held only for the younger cohort and was no longer significant for the older cohort. This finding can be related to a series of interconnected reasons. The first one is the developmental convergence of the two domains. As suggested by Snow (2007) the relations between developmental domains may be present only at a certain moment of convergence. In that sense, the mediation role of executive functions on the relation between motor skills and pre-academic skills is present in an earlier developmental moment but becomes less pronounced at a later stage. Likewise, Davids, Pitchford and Limback (2011) argued that the motor-cognitive relation is age-dependent, as the different skills involved may develop at different rates. This could explain the differences found between the relations described in the younger and older cohort. Secondly, it is noticeable that in the oldest group there were strong positive relations between motor skills, pre-academic skills and executive functions at baseline (4.5 years old). In this way, the relations between the domains are largely explained by the concurrent relation at 4.5 years old (at that particular developmental moment) whereas the longitudinal relations maybe not be strong enough to maintain the mediated relation. In contrast with the study of Schmidt and colleagues (2017), in which baseline performance and relations were not included, our study shows that the concurrent relations have a strong impact on the longitudinal relations. Therefore, we recommend to include both baseline performance as well as concurrent relations in future studies exploring the motor-cognitive relation with a longitudinal design. The third reason is related to the operationalization of motor skills. In our sample, a general motor skills factor was considered and this could have an impact on the relations found. For example, in the review of Grissmer and colleagues (2010) including three national longitudinal studies, the authors reported a consistent positive relation between fine motor skills and specific components of pre-academic skills (like reading and math achievement) but did not find any significant relation with gross motor skills. The relations described among specific components may be faded out when including a general motor factor.

In addition, as part of the mediation model, we also explored the relation between motor skills and executive functions, and between executive functions and pre-academic skills in a concurrent—at baseline—and longitudinal manner. Our findings support the previous body of literature showing strong positive relations for both cohorts (except for motor skills and executive functions in 3.5-year-olds). These findings are relevant as they show, on the one hand, the critical role of motor skills on the development of executive functions, and on the other hand the influence of executive functions on the development of pre-academic skills in Mexican young children. Therefore, we follow the recommendations of Diamond and Lee (2011) that—in order to improve executive functions and academic achievement—researchers, practitioners and policymakers, should not focus narrowly on those skills, but expand the focus to other relevant developmental domains. Our study contributes to clarifying how these relations are portrayed in young children, and therefore it may work as a guide for teachers, practitioners and policymakers in the development of an integrative ECE curriculum that addresses different developmental domains to aid the enhancement of (pre)academic achievement.

Conclusively, our study adds to the current knowledge of the motor-cognition relation by empirically examining the often-assumed structures of the studied constructs. In this way, we first addressed the composition of the constructs in the two age groups of young children. In our study we replicated the same model, including the same tasks and same factor structure (after explicitly testing both)—in both cohorts, allowing us to make a cleaner comparison between the groups. Additionally, we explored the relation from a longitudinal perspective in two different, but overlapping age groups of young children. Hence, we obtained a proxy of a general picture of the relation of motor skills, executive functions and pre-academic skills across a wide range of the early childhood period, while also exploring how these relations are represented in a younger and an older group. Furthermore, we accounted for initial performance of executive functions and pre-academic skills and their relations with motor skills at baseline level, which allowed us to disentangle the temporal nature of the interrelations. Collectively, it seems that the motor-cognition relation depends heavily, on the one hand, on the age group addressed, and, on the other hand, on the way the constructs are conceptualized and operationalized.

3.4.1 Limitations and recommendations for future research

One of the limitations in our study was the relatively small sample size for a complex model. Our decision to study younger and older children separately enabled us to test more specific relations, but also reduced our sample size. This had an impact on the power of our analysis. It may be that with a bigger sample size the full-mediation effect of executive functions will hold significance in both age groups, even after including base-line performance and relations.

Additionally, we explored both groups as a proxy to portray the entire ECE period. However, with a full longitudinal design, we could have been better able to explore these relations during the early childhood years. In designing such studies, researchers should be aware of the challenges in the selection of measurement instruments that are developmentally appropriate and sensitive for younger and older children, as well as the imperative need to empirically test measurement invariance as a preparatory analytical step to ensure a more accurate reflection of the constructs and, therefore, of their relations.

Finally, due to the intrinsic nature of our data we could neither explore the specific influences of gross and fine motor skills, nor the specific influences of working memory and inhibitory control on pre-numeracy and pre-literacy. Examining specific components of motor skills could help unravel the intricate motor-cognitive relation in young children further. Nonetheless, we agree on the added value of addressing the relations also at a general level—especially because that was the better representation of the data in our sample.

In conclusion, our study showed that the combination of age span and the structure of the constructs are key factors when examining the motor-cognitive relation. Therefore researchers should undertake a thoughtful delimitation of the age group to be addressed and explore the structure of the constructs in relation to their samples, which are particularly important in longitudinal studies.

Chapter 4

DEVELOPMENT OF SOCIOEMOTIONALCOMPETENCE AND THE BIDIRECTIONAL RELATION WITH HOTAND COOL EXECUTIVE FUNCTIONS IN YOUNG CHILDREN

Development of Socioemotional Competence and the Bidirectional Relation with Hot and Cool Executive Functions in Young Children

Abstract

This study explored the bidirectional relation between socioemotional competence (SEC) and executive functions in 279, three-, four- and five-year-old Mexican children. Profiles of socioemotional competence were identified at each age based on children's emotional and behavioral data. A bidirectional relation was found between the membership to SEC profiles and cool executive function (inhibitory control), but not with hot executive function (delay of gratification). High inhibitory control at age 4.5 reduced the probability of belonging to an 'aggressive' profile at age 5.5. Furthermore, children who were able to recognize their emotions at age 4.5 were more likely to perform higher on the inhibitory control tasks at age 5.5. Implications for practice and the relevance of an integrative assessment of SEC are discussed.

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4.1 Introduction

The early childhood years (ages 3 to 6) are marked by a dramatic brain and cognitive development, and are crucial to the development of socioemotional competence (SEC; Denham, Way, Kalb, Warren-Khot, & Basset, 2013; Zelazo, Qu, & Kesek, 2010). Both social and emotional components grow intertwined in this phase: social competence gains importance as the direct interactions and engagement with peers expand (Campbell et al., 2016), while emotional competence aids children to respond in an appropriate and socially accepted manner towards their peers (Lemerise & Harper, 2014). SEC during the early years represents the foundation for young children's later development and is critical for their school readiness, classroom adjustment and general school success (Denham, 2006; Denham et al., 2013; Halle & Darling-Churchill, 2016). In the same period, children undergo great advances in the development of their executive functions (EF), a set of "higher order, self-regulatory, cognitive processes that aid in the monitoring and control of thought and action" (Carlson, 2005, p. 595). A vast body of research highlights the importance of EF for the development of social skills, recognizing their contribution to self-control, emotion regulation, prosocial behaviour and social competence (Carlson & Wang, 2007; Huyder & Nilsen, 2012; Katzir Eyal, Meiran, & Kessler, 2010 Rhoades, Greenberg, & Domitrovich, 2009). Recent studies suggest a bidirectional association between EF and SEC, in which emotions and social interactions also supply a significant input for the executive development (Ferrier, Bassett, & Denham, 2014; Hala, Pexman, Climie, Rostad, & Glenwright, 2010). However, research that empirically explores the bidirectional association between EF and SEC is still incipient. Moreover, our current understanding of children's SEC has been restricted mostly to parent and teacher reports, and therefore our knowledge about direct child expressions of SEC is limited. Finally, current research has almost exclusively been conducted in Western samples, thereby restricting our understanding of what it means to be socioemotionally competent in other cultural contexts.

With the present study, we add to the scarce body of studies addressing a possible bidirectional relation between EF and SEC in early childhood. We do this by investigating two types of executive functions—hot and cool EF—as they might reveal distinctive relations with SEC. Additionally, responding to the multidimensional character of the construct, we characterize SEC from a person-centered approach, instead of the traditional variable-centered approach that disregards its multidimensionality. Finally, we make use of direct child measures instead of the dominant operationalizations of SEC that rely on parent-teacher questionnaires, as a means to more openly capture direct expressions of the construct, even those that might be unique to the cultural context where the study is situated.

4.1.1 Development of socioemotional competence

Socioemotional competence (SEC) encompasses a set of social and emotional skills that are inextricably interrelated. Social competence includes the capability to develop positive relations with others, the ability to communicate feelings and coordinate actions with a social partner, and the capacity to identify and regulate emotions and actions (Campbell et al., 2016). Emotional competence refers to the children's ability to recognize emotions—their own and from others—and the capability to express such emotions in a cultural and socially competent way (Camras, Shuster, & Fraumeni, 2014). Emotional competence is an essential contributor to social competence, as it allows children to regulate their behavior and act in a socially competent manner (Camras, Shuster, & Fraumeni, 2014). Furthermore, having positive peer relations may boost and provide an atmosphere that helps children refine their emotional and social competence (Lemerise & Harper, 2014).

During the early childhood years, children start to develop emotional connections outside their family circle, initiate peer interactions and start to build friendships. In this period, prosocial behaviors emerge, and children are expected to acquire the capability to distinguish between socially acceptable and unacceptable behaviors (Denham et al., 2006; Halle & Darling-Churchill, 2016). By the end of the early childhood years, children who achieve a solid emotional foundation are able to anticipate, talk about, and understand their own and others' feelings and utilize these skills to better navigate the daily social interactions (National Scientific Council on the Developing Child, 2004).

4.1.2 Challenges on the assessment of SEC

Despite the expanding interest in the development of SEC, the field is still facing two crucial challenges regarding its assessment. Firstly, SEC in early childhood has been traditionally assessed employing parent and teacher reports, thereby relying on their observations and experiences about the child's social and emotional competencies. However, recently Jones, Zaslow, Darling-Churchill, and Halle (2016) highlighted the importance of direct child assessments to counteract the assessor-bias resulting from the sole reliance on parent and teacher reports. Secondly, most of the studies addressing SEC have been conducted in Western cultures. Although there is general agreement about the set of skills that SEC encompasses, the appreciation of these skills may differ depending upon social context (Campbell et al., 2016; Camras, Shuster, & Fraumeni, 2014). For example, the way adults conceptualize socially competent behavior in young children may vary depending on sex, ethnicity or culture (Campbell et al., 2016). Likewise, parent beliefs, values, and their attitudes towards the children's emotions, consciously or not, result in cultural differences in the way children develop and express emotions (Camras, Shuster, & Fraumeni, 2014). Furthermore, cultural differences have also been reported in the preferences on problem-solving strategies. Gabrielidis, Stephan, Ybarra, Pearson, and Villareal (1997) reported that in cultures traditionally seen as collectivistic, conflictive situations tend to be avoided and harmony is prioritized in the conflict-solving. In contrast, in cultures that are considered individualistic, competitive strategies are preferred. However, there are inclusive differences within the individualistic cultures (for example the Canadian and the American) and collectivistic cultures (for example, the Asian and the Latino) as described by the authors.

4.1.3 Young children's hot and cool executive functions

Executive functions (EF) refer to a compound of high-order cognitive processes that are involved in the monitoring and control of thought and action (Carlson, 2005). Zelazo and Müller (2002) proposed a distinction between "Hot" and "Cool" executive functions. Hot EF are evoked by affectively non-neutral tasks, and involve affective and motivational processing, demanding constant evaluations of the affective self-significance of stimuli—reward or punishment (Zelazo & Cunningham, 2007; Zelazo, Qu, & Kesek, 2010). They often involve the ventral parts of the prefrontal cortex and are usually associated with the ventral anterior cingulate circuitry—associated with other reward and social structures (Lee, Walker, Hale, & Chen, 2017; Zelazo & Cunningham, 2007). Delay of gratification is considered to be the most typical hot EF task, as it is triggered by situations where attractive and salient rewards are at stake (Shoda, Mischel, & Peake, 1990). On the other hand, Cool EF are the most studied of these cognitive functions. Cool functions are those that involve decontextualized problems and are relatively abstract. Cool EF are often associated with the lateral prefrontal cortex and the dorsolateral prefrontal and dorsal anterior cingulate circuitry—that is linked with other cortical areas. (Lee, Walker, Hale, & Chen, 2017; Zelazo & Cunningham, 2007). There is general agreement on the existence of three core cool EF: (1) Working memory, which refers to the ability to monitor and revise information; (2) Shifting, referring to the ability to switch between multiple tasks; and (3) Inhibitory control, which refers to the ability to suppress pre-potent responses (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000).

4.1.4 Relations between cool and hot EF and socioemotional competence

Traditionally, research has addressed the relation between EF and SEC with the premise that the first one precedes the latter. Furthermore, since research on EF has largely focused on cool EF, the study of their relation to SEC has also mainly concentrated on cool rather than hot EF. However, given the different types of cognitive and motivational processing involved in cool and hot EF, it can be expected that each EF type shows a different association with SEC.

In particular, inhibitory control has been largely depicted as the mechanism that contributes to successful self-control and it has been related to the development of emotion regulation and SEC (Carlson & Wang, 2007; Katzir Eyal, Meiran, & Kessler, 2010; Rhoades, Greenberg, & Domitrovich, 2009). It is regarded as a key internal resource for young children to face the social challenges presented by a preschool classroom (Rhoades et al., 2009). Inhibitory control permits children to suppress inappropriate or aggressive behavior, and to increase cooperative behaviors, which are necessary in order to act collaboratively with a partner (Huyder & Nilsen, 2012). For example, children who inhibit their natural tendencies to be physically aggressive, are perceived as better play partners and, consequently, as more socially competent (Rhoades, Greenberg, & Domitrovich, 2009). More specifically, in a study with ‘hard to manage’ children, it was found that these children presented impaired inhibitory control, but intact planning, working memory and shifting (Brophy, Taylor, & Hughes, 2002).

In the case of hot EF, only few longitudinal studies have examined the relations between the delay of gratification and SEC in young children. Funder, Block, and Block (1983) observed 116 four-year-old children and related a composite delay of gratification score (based on two tasks) with personality ratings at middle childhood. They reported that children who did not delay gratification at age four were broadly described as irritable, aggressive, restless, lacking self-control, whiny, easily offended and poor at coping with stress at ages 7 and 11. Mischel, Shoda, and Peake (1988) studied 95 four-year-old children and examined the delay of gratification abilities on a self-imposed marshmallow delay task. They reported that the amount of time that children delayed gratification was significantly and positively related to their social competence measured at age 15. A more recent study by Paulus et al. (2015) found that the ability to delay gratification of 70 children at 24 months old was positively and significantly correlated with the ability of children to share with friends at 60 months of age. Likewise, Chen, Zhang, Chen, and Li (2012) found that a delay of gratification composite (based on two tasks) of 175 two-year-old Chinese children was positively associated with their social competence reported by mothers at age 11, and negatively predicted emotional problems at the same age.

Moreover, a couple of comprehensive studies have include hot and cool EF simultaneously to explore their relation with SEC. Firstly, Willoughby, Kupersmidt, Voegler-Lee and Bryand (2011) studied 926 young children between 3 and 5 years old, and reported that when cool and hot EF were analyzed separately, both correlated negatively with disruptive behavior and positively with academic achievement. However, when analyzed together, the cool tasks correlated only with academic achievement, whereas hot tasks were solely associated with disruptive behaviors. Secondly, Denham and colleagues (2014) in a longitudinal study including 316 three- and four-year-olds explored the associations between cool and hot tasks and socioemotional child responses to hypothetical challenging social situations. The authors reported that cool components showed more and stronger relations with emotional and behavioral responses—concurrently and longitudinally—than hot components. In general, both components were related to the decrease of less adaptive responses—like 'aggressive' or 'happy' ones—and showed positive associations with 'sad' and 'prosocial' responses—which are considered more adaptive responses.

4.1.5 A bidirectional perspective

There is growing agreement among researchers on the importance of social and emotional influences on the development of cognition. Campbell and colleagues (2016), for example, proposed a conceptual model of socioemotional learning in which they considered that social, emotional and cognitive domains are interrelated and reciprocally influence one another. Likewise, Lewis and Carpendale (2009) reflected on the socialization of executive functions and—based on a Vygotskian perspective—consider the development of EF as a natural consequence of socialization, as social interactions and conventions stimulate cognitive development. Additionally, the neural model proposed by Zelazo and Cuningham (2007) highlights that cognition and emotion are intricately interconnected, and that emotion and cognition are inseparable entities that should be seen as two integral aspects of a continuum.

Whereas there is a constant interaction between emotion and cognition over the lifespan, the influence of emotional context on the development of EF seems to be stronger in the early childhood (Zelazo, Qu, & Kesek, 2010). Moreover, the possible bidirectionality of this relation has been hypothesized involving emotional and social aspects. On the one hand, emotions may aid children to organize their thinking, learning, and actions, while cognitive processes also have an essential role in regulating children's emotions (Carlson & Wang, 2007).On the other hand, the development of EF not only influences the emerging social understanding in young children but is also influenced by social interactions (Hala et al., 2010). Although theoretically there seems to be sufficient ground to assume a two-way relation between SEC and EF, research empirically addressing the bidirectional nature of the relationship is still incipient. To our knowledge, only Ferrier, Bassett and Denham (2014) have empirically tested a bidirectional relation, including emotionality (emotional expression and experience) and executive functions. They assessed 175 children between 3 and 5 years old on two occasions. The authors reported that emotionality was related with EF concurrently (based on a direct assessment) and longitudinally (based on teacher's report), whereas EF (based on a direct assessment) positively predicted emotionality at time 2, and concluded that there is a reciprocal relation between EF and emotionality in young children.

4.1.6 The present study

We explore the development of Mexican young children's socioemotional competence (SEC), and its relations to the development of hot and cool executive functions (EF). Based on the need for a better understanding of children's expressions of SEC, our study is based on a direct assessment rather than the traditional parent or teacher questionnaire, which allows us to better capture children's socioemotional expressions by reducing assessor-bias. Moreover, we adopt a person-centered approach instead of the traditional variable-centered approach, which allows us to capture the co-occurrence of social and emotional child expressions. Additionally, we describe the emerging socio-emotional expressions of young children, instead of the frequently used, pre-determined distinctions between competent and non-competent responses. This descriptive attribute also makes our assessment more culturally sensitive. Furthermore, longitudinal data allows us to investigate these profiles over the entire early childhood education period, and to portray how children transition between, or remain within these profiles. Finally, we empirically test whether the relation between hot and cool EF and SEC throughout the early childhood years is uni- or bidirectional. We focus on inhibitory control as a cool EF and delay of gratification as a hot EF due to their previously reported relevance for the development of SEC.

4.1.7 Aims and research questions

The aim of this study is twofold. The first aim is to examine socioemotional profiles of young children and their developmental trajectories (RQs 1a, 1b, and 1c). The second aim is to explore the association between hot and cool executive functions and membership to those profiles, and to determine whether this association is bidirectional (RQs 2a and 2b). Therefore our research questions are:

1. (1a) Which profiles of children's socioemotional responses to social challenges can be identified? (1b) Are the identified profiles equivalent during the entire early childhood education period? (1c) How do children transition among the SEC profiles over time?

2. (2a) Do hot and cool executive functions predict child membership to SEC profiles? (2b) Does the child membership to a SEC profile predict the performance on hot and cool executive functions?

4.2 Method

4.2.1 Research context and design

This study was conducted in Mexico City. Early childhood education (ECE) in Mexico is obligatory starting at age 3. Children are expected to complete three years of ECE before starting primary education: ECE 1 (3 to 4 years old), ECE 2 (4 to 5 years old) and ECE 3 (5 to 6 years old). In collaboration with the Preschool Sectorial Directorate from the Ministry of Education, five public ECE centers from the urban area of Mexico City were recruited to participate. Sixty children per center were invited to participate, 300 in total. As our focus was on typically developing children, those identified by the Special Needs Education Unit (UDEEI) were not considered for participation. A longitudinal assessment was planned including four measurement occasions: January 2016, June 2016, January 2017 and June 2017. Children who were enrolled in the study during ECE 1 (cohort 1) were assessed at halfway and end of ECE 1, and at halfway and end of ECE 2. Children who were in ECE 2 at the start of the study (cohort 2) were assessed at halfway and end of ECE 2, and at halfway and end of the ECE 3. We used an accelerated longitudinal design merging cohort 1 and cohort 2 to transform the four measurement occasions into six time points, covering in this way the three-year ECE period, as explained in Table 4.1.

Table 4.1 *Transformation of the longitudinal data collection into the accelerated longitudinal design*

Original format of longitudinal data collection						
	M1	M2	M3	M4		
Cohort 1: ECE1 (*n*)	127	127	98	103		
Cohort 2: ECE 2 (*n*)	139	140	115	121		
Accelerated longitudinal design						
	ECE 1 Halfway[a] (T1)	ECE 1 End[b] (T2)	ECE 2 Halfway[a] (T3)	ECE 2 End[b] (T4)	ECE 3 Halfway[a] (T5)	ECE 3 End[b] (T6)
Cohort 1	M1	M2	M3	M4	*	*
Cohort 2	*	*	M1	M2	M3	M4

Note. M = measurement occasion, T = time point, * = Imputed data missing by design. ECE = early childhood education. [a] Assessed halfway of the school year (January). [b] Assessed at the end of the school year (June-July).

4.2.2 Procedure and participants

Parents or guardians of the children gave written consent for their children to participate. Ethical approval for this study was granted by the Ethics Committee of Pedagogical and Educational Sciences of the University of Groningen. For the evaluation of the children, six assessors were recruited and trained before the testing period. Assessors were all Mexican, graduate psychologists or psychology students with sufficient mastery of the testing procedures as demonstrated in practice sessions. Children were assessed individually in a separate testing room in pull-out sessions during regular school hours.

From the 300 children invited to participate, we obtained a final sample of 279 children among all time points. Table 4.2 provides an overview of the final sample characteristics. Two indicators were used to explore the sociodemographic characteristics: mother educational level and the monthly household income. Mother educational level was based on the International Standard Classification of Education (ISCED) of UNESCO. The highest proportion of mother educational level in our sample was lower secondary education. Household monthly income was assessed using Mexico's 2012 household income deciles (INEGI, 2012). As the study includes public ECE centers in low socioeconomic areas, nine ranges of household income were created based on the five lower deciles. About 64% of our sample reported a monthly household income corresponding to the first lower decile of the average household income of the country (less than 7,000 Mexican pesos, about 375 USD).

Table 4.2 *Sociodemographic characteristics of the sample*

	Cohort 1 (*n* = 134)	**Cohort 2 (*n* = 145)**	**Total sample (*n* = 279)**
Mother educational level (%)			
Pre-primary education	0	0.7	0.4
Primary education	13.8	12.1	13.0
Lower secondary education	40.0	30.7	35.2
Upper secondary education	26.9	37.1	32.2
Bachelor degree, specialization or master degree	19.2	19.3	19.3
Monthly income (%)			
Range 1-2 (1st decile)	66.9	61.2	63.9
Range 3-4 (2nd decile)	13.1	23.7	18.6
Range 5-6 (3rd decile)	12.3	9.4	10.8
Range 7-8 (4th decile)	4.6	0.7	2.6
Range 9 (5th decile or higher)	3.1	5.0	4.1
Sex (% female)	60.4	54.5	57.3
Age in months (*M*)			
ECE 1			
Halfway (T1)	43.7	43.6	43.6
End (T2)	47.4	47.3	47.3
ECE 2			
Halfway (T3)	54.9	55.6	55.3
End (T4)	59.5	59.3	59.4
ECE 3			
Halfway (T5)	66.9	66.7	66.8
End (T6)	71.5	71.2	71.3

Note. ECE 1= First year of early childhood education, ECE 2= Second year of early childhood education, ECE 3= Third year of early childhood education.

4.2.3 Missing data

Our intended sample was 300 children, from which we had an initial nonresponse of 7% (21 children), leading to a final sample of 279 children. From the 279 children participating, we had two sources of missing information: data missing by design and not-by-design. The data missing by design stem from T1, T2, T5, and T6 (marked with stars in Table 4.1) of our accelerated longitudinal design. This type of missing information is considered to be Missing Completely at Random (MCAR), because the missing mechanism is controlled by the researcher, and therefore it can be confidently treated with modern techniques for handling missing data (Little, 2013). The missing not-by-design refers to unexpected missings (e.g., dropout or absence during evaluation). From the final sample (n = 279) about 70% of the children completed four assessments (n = 194), 14.33% completed three assessments (n = 40), 13.97% have two assessments (n = 39), and 2.15% (n = 6) have only one assessment.

We simultaneously conducted multiple imputation for both types of missing data using the Multivariate Imputation by Chained Equations (MICE) package in R (Van Buuren & Groothuis-Oudshoorn, 2011). Additional information about the imputation process can be found in the Appendix A.

4.2.4 Instruments

Socioemotional competence. The Challenging Situation Task-Revised (CST-R, Denham, Way, Kalb, Warren-Khot, & Basset, 2013) is a pictorial forced-answer test in which children are presented with hypothetical peer-conflict situations. Each situation has a pictorial representation and a verbal description of the transgression. The name of the main character of the storyline was adapted according to gender (María for a girl and Juan for a boy), but the pictorial representations are gender neutral. After the presentation of each situation, children were questioned: “when that happens to you, how do you feel?” Four pictorial cards of emotions were presented, representing happy, sad, angry and, just ok emotional responses. The names of the emotions were explicitly mentioned while the cards were shown. Next, children were asked “what do you do?” and four behavioral cards were presented: avoid, prosocial, aggressive or cry. Each card was accompanied by a verbal description of the behavior, for example, “Go away and play with something else”. The order of presentation of the situations and the emotional and behavioral responses, changed randomly on every occasion. The number of endorsements of each type of behavioral and emotional responses across the six scenarios was used as a final score. Reliability analysis was based on the first assessment, which included data from all three years of ECE. The internal consistency of the scales was assessed by inter-item mean correlations, following the recommended cutoff value of $r > .15$ for broad constructs (as in Denham, Way, Kalb, Heather, Warren-Khot & Basset, 2013). The emotional response of 'just ok' and the behavioral response of 'cry' did not exceed the cutoff point ('just ok' inter-item $r = .10$; 'cry' inter-item $r = .13$) and therefore were not included in the analyses.

Inhibitory control (cool EF). We assessed inhibitory control with two tasks from the Neuropsychological Battery for Preschoolers: day-night and angel-devil (Batería neuropsicológica para preescolares, BANPE; Ostrosky, Lozano & González-Osornio, 2016). In the task day-night we presented two cards to the child, one depicting the sun and one depicting the moon. Children were asked to say 'day' when a moon-card was shown and 'night' when a sun-card was presented. A total of 16 trials were presented and one point granted per correct trial. For angel-devil children were asked to follow the instructions given by the angel and to ignore the instructions given by the devil. In this task, the points gained by the devil trials were used as the score. According to the scoring rules, two points were given if the children ignored the instruction given by the devil, one point if the children initiated the move but corrected themselves and zero points if the children performed the instruction (6 trials, maximum 12 points).

Delay of gratification (hot EF). We utilized two tests of delay of gratification from the Preschool Self-Regulation Assessment battery (PSRA; Smith-Donald, Raver, Hayes, & Richardson, 2007). The first test was Wrap the toy. In this test, the assessors told the children that they had a present for them, but have forgotten to wrap it. The children were helped to turn their chair (90 degrees from the assessor's side), and asked not to look until the assessor finished wrapping the present. The assessor made noises of wrapping the present for one minute. Time in seconds before the child's first peak was recorded. The second test was Snack delay; however, this test showed extreme ceiling effects in our sample and was therefore not utilized in the analyses.

4.2.5 Analytical strategy

Due to the complexity of the analysis and in order to facilitate the interpretability of the results, in the present study we utilized only three time points representing each year of the ECE: time 1, time 3 and time 5 (see table 4.1). All analyses were conducted using Mplus version 7.3 (Muthén & Muthén, 2015). The socioemotional profiles were defined by means of latent class analysis, with emotional and behavioral responses simultaneously included in the class analysis. Decisions about class enumeration were based on statistical indices and model usefulness (e.g., interpretability and parsimony). Different indices were taken into account: Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), Sample size adjusted BIC; Consistent Akaike's Information Criterion (CAIC) and Approximate Weight of Evidence Criterion (AWE). On all these indices the best model is the one with the smallest value; however, this value can continue to decrease with every addition of an extra class. Therefore, we adhere to the recommendations of Masyn (2013) and created plots from these indicators to find the elbow criterion, where the additional decrease of the value turns marginal. An entropy higher than .80 was desirable. Additionally, we checked the quality of classification in the final selected models (see Appendix C).

We followed the three-step approach to allocating children into the SEC profiles. On step one the best class solution was defined (as previously explained), on step two children were modally assigned to their most probable profile and, on step three the models of interest were run using step one's information about classification uncertainty to account for the error of classification. In order to investigate how children transition among the identified SEC profiles, we performed a latent transition analysis from time 1 to time 3, and from time 3 to time 5.

To test the bidirectionality of the relation between SEC profile membership and hot and cool EF, some transformations were needed in the executive functions variables. To create the cool EF indicator, the scores of the day-night task and the angel-devil task were parceled and transformed into performance categories based on standardized scores at each time point. The 'Low' category included children who performed below $z = -1$, the 'Medium' category included children between $z = -1$ and $z = 1$, and the 'High' category included children that performed higher than $z = 1$. For the hot EF indicator, the score of the 'wrap the toy' task was dichotomized as waiter for children who waited the complete time and non-waiter for children who peeked once or more before the time ended.

Finally, to explore the association between SEC profiles and EF categories, a cross-lagged model was tested employing an associative latent transition analysis (ALTA). ALTA models explore the dependency between two changing categorical latent variables by describing how the class membership in one categorical variable is associated with the class memberships of the other variable (Flaherty, 2008). ALTA was performed in a stepwise manner: (a) a model including cool EF and SEC at time 1 and 3; (b) a model including cool EF and SEC at time 3 and 5; (c) a model including hot EF and SEC at time 1 and 3; and (d) a model including hot EF and SEC at time 3 and 5. The ALTA models were tested starting with a highly restrictive model (independent development trajectories), building up to cross-sectional associations, and finally testing a less restrictive model including longitudinal associations. Wald tests were used for model comparisons, where a $p < .05$ was indicative of a significant improvement of the model. Furthermore, due to the nature of the accelerated design, we checked for cohort differences for mother educational level, monthly income, and our focus variables—SEC, hot EF, and cool EF—in all time points; none of these tests revealed significant cohort differences.

4.3 Results

4.3.1 Socioemotional profiles

The socioemotional profiles were extracted from each time point independently. Table 4.3 shows the diagnostic indicators for the different class solution models. Gray marked cells reflect the best performing models based on each indicator.

Based on plots, interpretability and class size, the final models selected were: at time 1 the model with four classes, at time 3 the model with five classes, and at time 5 the model with four classes. Figure 4.1 reflects the proportions of each emotional and behavioral response represented on the identified profiles per time point (exact values of the average frequency per type of response are given in the Appendix D). At time 1 and 3, profiles were mainly defined by the emotional answers rather than by behavioral responses; however, at time 5, both emotional and behavioral responses played a role in the classification process. At time 1, the first class (C1.1) contained children who responded 'mostly happy', class 2 (C1.2) consisted of a mix of 'happy & sad-angry', class 3 (c1.3) contained children who responded 'angry' and class 4 (C1.4) consisted of children who gave predominantly 'sad' responses. At time 3, class 1 (C3.1) referred again to children that responded 'mostly happy', the second class (C3.2) again consisted of a mix of 'happy & sad-angry' responses, the third class (C3.3) contained children who responded predominantly 'angry', class four (C3.4) consisted of a mix of 'sad & angry' and the fifth class (C3.5) consisted of children who gave mainly 'sad' responses. At time 5, children in the first class (C5.1) responded 'mostly happy', in class 2 (C5.2) they consisted of a mix of 'angry-sad & aggressive', class 3 (C5.3) contained children with a mix of 'sad-angry & avoidant' and finally class 4 (c5.4) contained children with a 'sad-angry & prosocial' profile.

Table 4.3 *Diagnostic of class solution of socioemotional profiles per time point*

K Class	Free par	Log-like	AIC	BIC	Adj BIC	CAIC	AWE	Entropy	Min %	Max %
Time 1										
2	19	-2967.05	5972.10	6041.10	5980.85	6060.10	6205.09	.82	.36	.63
3	26	-2844.95	5741.89	5836.30	5753.85	5862.30	6060.71	.87	.27	.39
4	33	-2776.29	5618.58	5738.41	5633.77	5771.41	6023.24	.91	.32	.20
5	40	-2746.06	5572.12	5717.37	5590.53	5757.37	6062.62	.90	.14	.31
Time 3										
2	19	-2974.3	5986.59	6055.59	5995.34	6074.59	6219.58	.96	.14	.86
3	26	-2880.22	5812.44	5906.85	5824.41	5932.85	6131.26	.94	.13	.72
4	33	-2826.18	5718.35	5838.18	5733.54	5871.18	6123.01	.86	.13	.50
5	40	-2758.21	5596.42	5741.67	5614.84	5781.67	6086.92	.88	.09	.37
6	47	-2730.96	5555.92	5726.59	5577.55	5773.59	6132.25	.88	.05	.29
Time 5										
2	19	-2833.19	5704.37	5773.37	5713.12	5792.37	5937.36	1.00	.04	.95
3	26	-2723.01	5498.02	5592.43	5509.99	5618.43	5816.84	.91	.04	.62
4	33	-2616.84	5299.67	5479.50	5314.86	5452.50	5704.33	.93	.04	.50
5	40	-2570.14	5220.27	5365.52	5238.68	5405.52	5710.77	.95	.01	.50

Note. Free par= number of free parameters; AIC = Akaike's Information Criterion; BIC = Bayesian Information Criterion; Adj BIC = Sample size adjusted BIC; CAIC = Consistent Akaike's Information Criterion; AWE = Approximate Weight of Evidence Criterion; Min % = proportion of the smallest class; Max % = proportion of the largest class. Gray marked cells reflect the best performing models based on indicators.

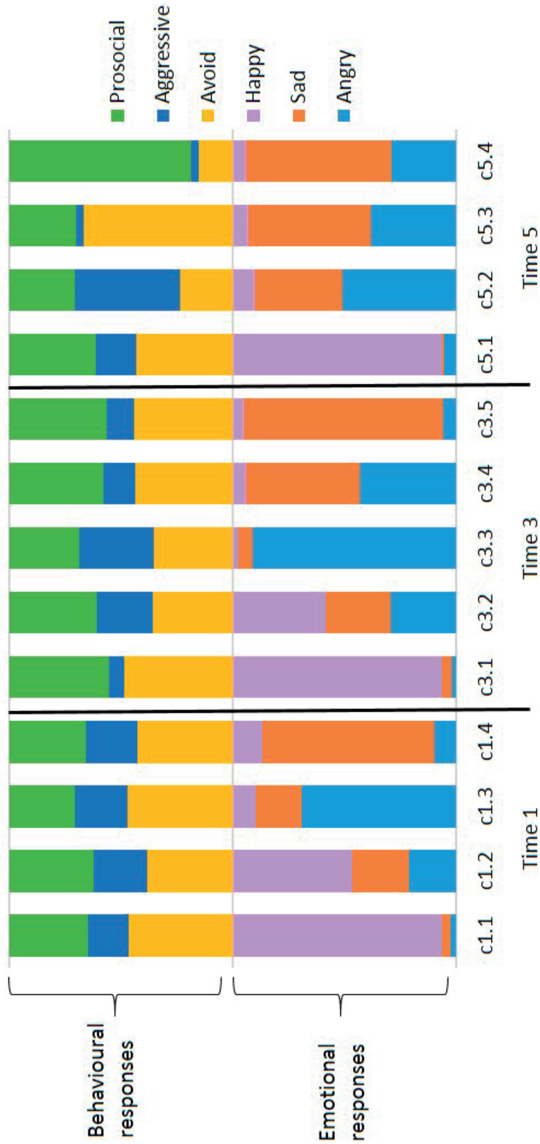

Figure 4.1. Socioemotional profiles based on proportions of each emotional (angry, sad and happy) and behavioral (avoid, aggressive and prosocial) responses at time 1, 3, and 5.

4.3.2 Transitions among SEC profiles, inhibitory control, and delay of gratification

Table 4.4 presents how many children were allocated to each of the SEC profiles (based on the most probable profile membership), as well as the distribution of children over the levels of cool EF (inhibitory control) and hot EF (delay of gratification).

The transition probabilities for each category-construct from time 1 to time 3 and from time 3 to time 5 are presented in Table 4.5. The autoregressive paths for inhibitory control showed that children coming from a high-performance group at time 1 are 2.87 times more likely to belong to the high performers at time 3 than the low performers at time 1 *OR* = (0.19/(1-0.19)) / (0.08/(1-0.08)). The level of inhibitory control at time 5 was not significantly predicted by the level of inhibitory control at time 3, as shown by the high probability of all children to belong to the high performing group at time 5. As for delay of gratification, we found no relation between being a 'waiter' and 'non-waiter' at time 1 and their performance at time 3. Even though most children transitioned to 'waiter' at time 5, children coming from the 'non-waiter' category at time 3 were almost two times more likely to remain in that category at time 5 compared to 'waiters' at time 3 (*OR* = 1.94).

Figure 4.2 shows the developmental trajectories of SEC. The probabilities of belonging to the profiles 'Mostly happy' (C3.1) and 'Sad'(C3.5) at time 3 did not change according to the previous SEC profile; however, children that had a 'Happy-sad-angry' profile (C1.2) at time 1 were 1.68 times more likely to belong to the 'Happy-sad-angry' profile (C3.2) than 'Sad' children (C1.4). In the same way, children coming from an 'Angry' profile at time 1 (C1.3) had the highest probability of belong to the 'Sad-Angry' profile (C3.4) at time 3.

The profile 'Mostly happy' (C5.1) at time 5 was the least frequent profile and children coming from the 'Mostly happy' profile (C3.1) at time 3 were more likely to stay in this profile. Children with an 'Angry' profile (C3.3) at time 3 were almost three times (OR = 2.89) more likely to belong to the 'Angry-sad & aggressive' profile (C5.2) than children on the 'Sad-angry' (C3.4) profile. There was no meaningful change in probabilities of belonging to the 'Sad-angry & prosocial' profile (C5.4) based on the previous SEC profile.

Table 4.4 *Counts and proportions of children per category*

Construct	Time	Category	Count	Proportion
Socioemotional Competence	T1	C1.1 'Mostly happy'	64	.23
		C1.2 'Happy-sad-angry'	90	.32
		C1.3 'Angry'	67	.24
		C1.4 'Sad'	58	.21
	T3	C3.1 'Mostly happy'	36	.13
		C3.2 'Happy-sad-angry'	64	.23
		C3.3 'Angry'	29	.10
		C3.4 'Sad-Angry'	107	.38
		C3.5 'Sad'	43	.15
	T5	C5.1 'Mostly happy'	11	.04
		C5.2 'Angry-sad & aggressive'	36	.13
		C5.3 'Sad-angry & avoidant'	144	.52
		C5.4 'Sad-angry & prosocial'	87	.31
Cool EF (inhibitory control)	T1	Low	46	.16
		Medium	186	.67
		High	47	.17
	T3	Low	55	.19
		Medium	184	.66
		High	40	.14
	T5*	Low	35	.12
		Medium	244	.87
Hot EF (delay of gratification)	T1	Non-waiter	179	.64
		Waiter	100	.36
	T3	Non-waiter	84	.30
		Waiter	195	.70
	T5	Non-waiter	31	.11
		Waiter	248	.89

Note. *Only 2 categories of performance due to a ceiling effect.

4

Table 4.5 *Transition probabilities from T1 to T3 and T3 to T5*

Cool EF - Inhibitory control

		T3					T5	
		Low	Medium	High			Medium	High
	Low	.26	.65	.08		Low	.24	.75
T1	Medium	.20	.65	.14	T3	Medium	.09	.90
	High	.11	.70	.19		High	.09	.90

Hot EF - Delay of gratification

		T3				T5	
		Non- waiter	Waiter			Non-waiter	Waiter
T1	Non- waiter	.30	.69	T3	Non-waiter	.16	.83
	Waiter	.29	.70		Waiter	.09	.91

Socioemotional competence

		T3							T5			
		C3.1	C3.2	C3.3	C3.4	C3.5			C5.1	C5.2	C5.3	C5.4
	C1.1	.14	.23	.13	.33	.17		C3.1	.11	.11	.47	.30
T1	C1.2	.13	.27	.09	.38	.13		C3.2	.03	.13	.50	.33
	C1.3	.11	.22	.07	.43	.16	T3	C3.3	.00	.23	.46	.29
	C1.4	.14	.18	.12	.39	.16		C3.4	.04	.09	.56	.29
								C3.5	.02	.16	.47	.33

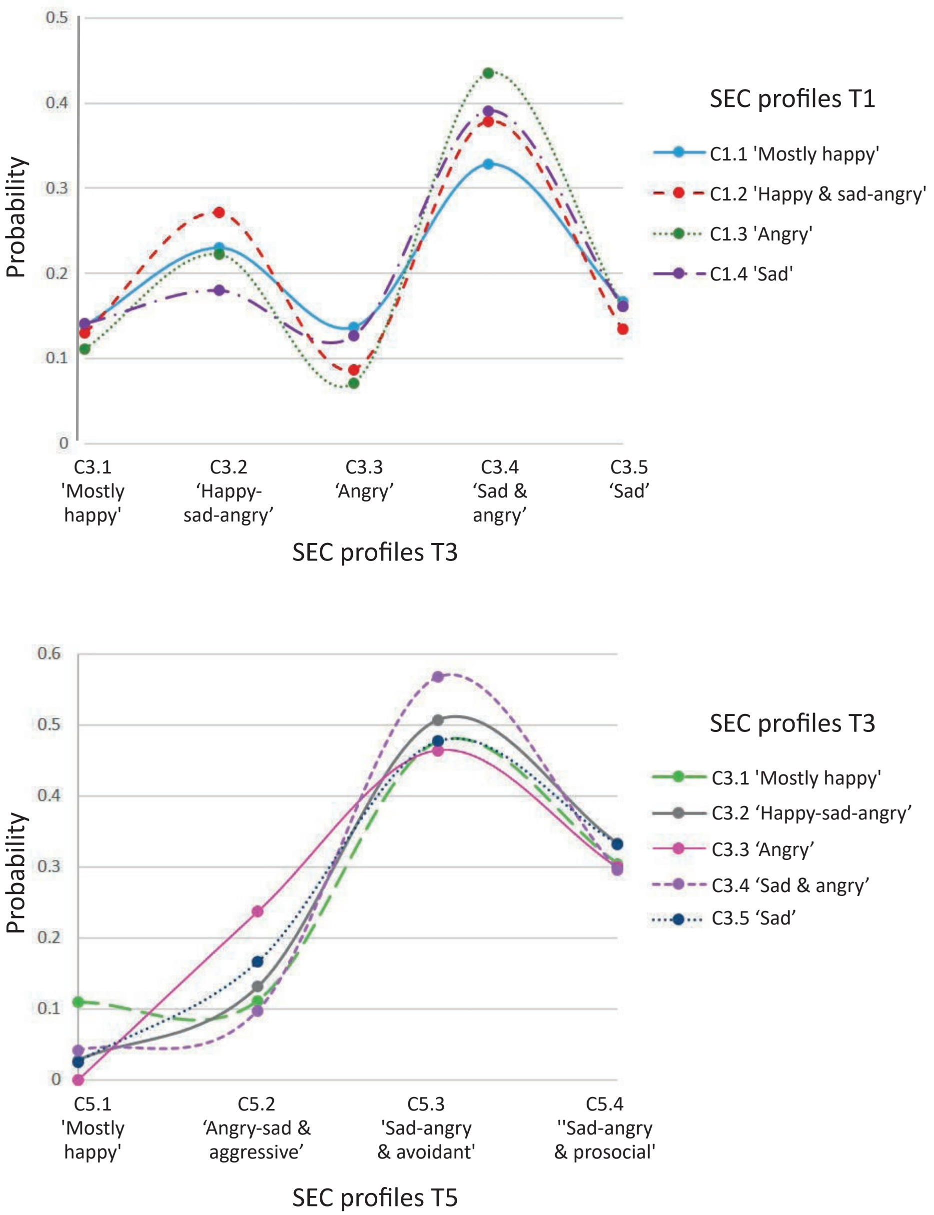

Figure 4.2. Transition probabilities of belonging into a SEC profiles from time 1 to time 3 and time 3 to time 5.

4

4.3.3 Bidirectional relation between SEC profiles and hot and cool EF

The results from the set of models tested to address the associative latent transition analysis are presented in Table 4.6. Only the longitudinal models at time 3 and time 5 including cool EF (inhibitory control) and SEC showed significant results.

Table 4.6 *Models tested for the associative latent transition analysis*

	Model	Free par.	LL	LL-SD	Wald test	*df*	*p*
SEC-Cool EF	Independent T1-T3	27	-1273.84	9.75			
	Independent T3-T5	24	-1064.80	8.24			
	Cross-sectional T1	29	-1273.06	9.47	.82	2	.66
	Cross-sectional T3	29	-1271.12	9.06	2.65	2	.26
	Cross sectional T5	27	-1062.85	7.92	2.63	3	.45
	Longitudinal INH1 to SEC3	29	-1272.61	8.72	1.04	2	.59
	Longitudinal SEC1 to INH3	30	-1271.75	10.91	1.61	3	.65
	Longitudinal INH3 to SEC5	27	-1061.08	7.91	65.67	3	<.001
	Longitudinal SEC3 to INH5	28	-1059.08	8.67	42.49	3	<.001
SEC-Hot EF	Independent T1-T3	22	-1145.07	8.11			
	Independent T3-T5	22	-986.90	12.23			
	Cross-sectional T1	25	-1144.18	7.63	0.37	3	.94
	Cross-sectional T3	26	-1143.67	8.25	1.30	4	.86
	Cross sectional T5	25	-984.58	11.52	1.84	3	.60
	Longitudinal DG1 to SEC3	26	-1141.76	9.18	4.33	4	.36
	Longitudinal SEC1 to DG3	25	-1142.37	7.91	3.49	3	.32
	Longitudinal DG3 to SEC5	25	-985.08	12.47	.34	3	.95
	Longitudinal SEC3 to DG5	26	-985.28	12.42	.52	4	.97

Note. SEC = socioemotional competence, EF = Executive functions, INH = inhibitory control, DG = delay of gratification, Free par. = Number of free parameters, LL = Loglikelihood.

Figure 4.3 presents the changes of probabilities of belonging to a certain SEC profile at time 5 based on the previous performance on inhibitory tasks at time 3. No relevant differences were found between levels of inhibitory control at time 3 for the profiles 'Mostly happy' (C5.1) and 'Sad-angry and prosocial' (C5.4) at time 5. However, there was a reduced probability of belonging to the profile 'Angry-sad & aggressive' (C5.2) for children with a high inhibitory performance at time 3 in comparison with low and medium performers ($OR = 5.57$). Moreover, high performers in inhibitory tasks at time 3 showed higher probabilities of belonging to the profile 'Sad-angry & avoidant' (C5.3) at time 5 as compared to low and medium performers. belonging to the profile 'Sad-angry & avoidant' (C5.3) at time 5 as compared to low and medium performers.

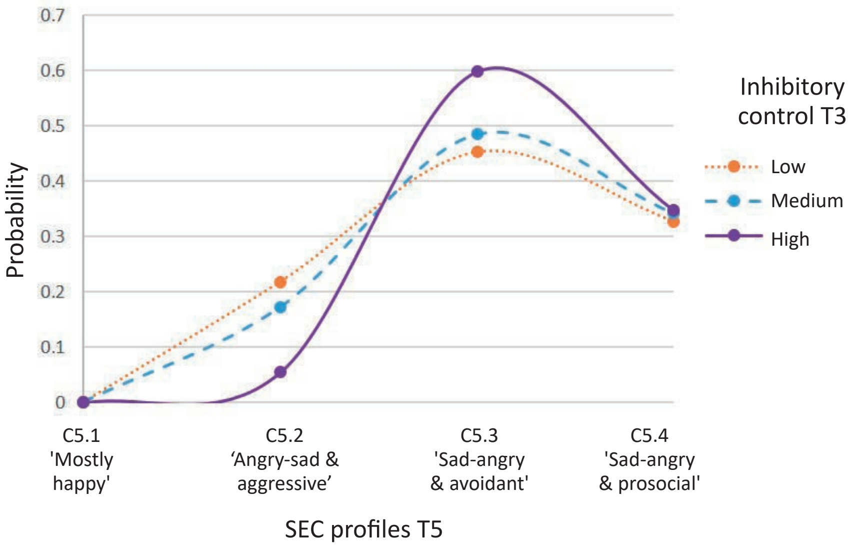

Figure 4.3. Probability of SEC membership at T5 based on inhibitory control performance at T3.

The changes in probabilities of pertaining to one of the levels of inhibitory performance according to the prior SEC profile membership are presented in Figure 4.4. The SEC profile 'mostly happy' (C3.1) had the highest probability to perform low (0.24) on the subsequent inhibitory tasks, and these children were 4.83 times more likely to be in the low-performance group at time 5 than children with the 'Sad-angry' profile (C3.4), for example. In contrast, the socioemotional profiles 'Angry' (C3.3) and 'Sad & angry' (C3.4) at time 3 showed lower probabilities (.08 and

.07 respectively) of belonging to the low inhibitory performance group and higher probabilities (0.92 and 0.93 respectively) of belonging to the medium performance group, compared to the other profiles.

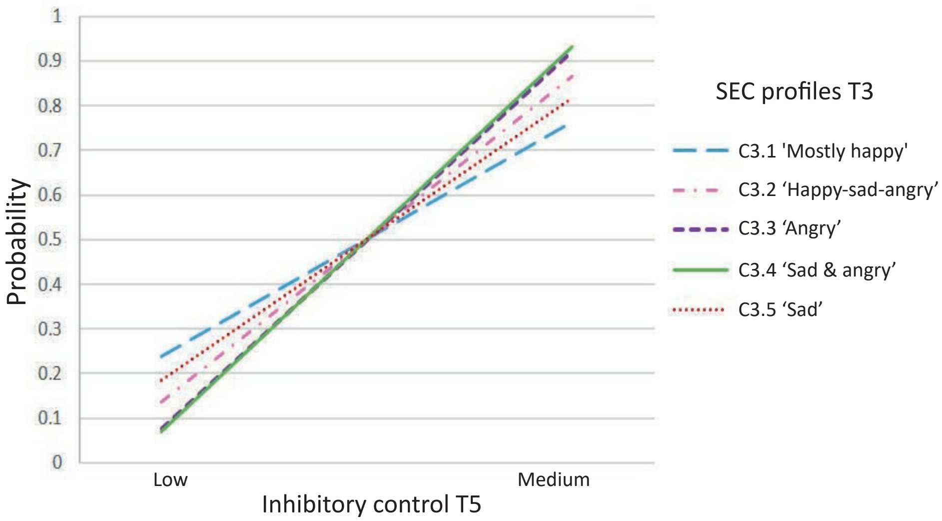

Figure 4.4. Probability of inhibitory control performance at T5 based on SEC profiles at T3.

4.4 Discussion

This study explored the socioemotional development of young children (from 3 to 6 years old) and its possible bidirectional relation with hot and cool executive functions. Our first aim was to identify socioemotional profiles of young children and to determine whether these profiles were equivalent across different ages of the early childhood period. Our explorations at three time points—with children aged on average 3.5 at time 1, 4.5 at time 2, and 5.5 at time 3—yielded a distinct set of four, five, and four socioemotional profiles respectively, representing different combinations of social and emotional child expressions. Whereas each set of profiles was different, we observed that in younger children (3.5 and 4.5 years old), socio-emotional competence (SEC) seemed to depend heavily on emotional recognition, and it is not until later in their development that the social responses become more distinct among profiles. These findings are in line with claims by Lemerise and Harper (2014), who indicated that emotional recognition helps children to manage the world of peers successfully and to respond in a socially accepted manner. Although

Lemerise and Harper did not explicitly propose a hierarchical order of development between emotional and social competence, our results suggest that emotional recognition is a precursor in the intricate socioemotional interplay.

Interestingly, a profile with children who respond 'mostly happy' to a conflictive situation was identified in all time points, yet, the number of children belonging to this profile decreased over time. This seems to suggest that there is a developmental process in which happy responses—evidence of low emotional recognition—are a reflection of an immature SEC. This is consistent with findings previously reported by Denham and colleagues (2014), who showed that younger children respond 'happy' more often than older children to the same conflictive situations. We also found that a high proportion of the older children in our sample (52%) responded in an avoidant way, a result that contrasts with the findings of Denham and colleagues (2014) who showed that even at four years of age, children decrease the frequency of avoidant responses and increase that of prosocial responses in comparison with three-year-old children. This discrepancy may be related to cultural differences. The sample in Denham's study stems largely from an Anglo-American culture—often described as an individualistic society—where a frontal approach to conflict is promoted. Our sample derives from the Mexican context—considered a collectivistic culture—where harmony is prioritized when solving conflicts, and therefore conflict avoidance is preferred (Gabrielidis, Stephan, Ybarra, Pearson, & Villareal, 1997). For example, a Mexican child that is being mocked may prefer to walk away instead of confronting the situation. The question remains open whether or not this kind of avoidant behavior is a competent socioemotional response. However, these particularities found in our SEC profiles reinforce the value of a descriptive approach based on direct child responses in revealing the context dependency of the construct.

It is important to notice that the identified SEC profiles vary in number and characteristics in the different age groups. In some cases—like the 'Mostly happy' profile—the main characteristics of the profiles were present consistently over time; however, most of the profiles were not consistent across the ECE years or showed only rough similarities. This finding, firstly, calls our attention to how we conceptualize SEC throughout the early childhood years, as our study has shown that even a one-year difference in age yielded a different characterization of SEC. This is highlighted by the idea of heterotypic continuity of developmental processes proposed by Petersen, Hoyniak, McQuillan, Bates, and Staples (2016), which suggests that a construct may show distinct manifestations at different developmental moments. Therefore, developmental researchers should be wary of the way they conceptualize and operationalize SEC. Secondly, it also has implications for what we may consider a socioemotionally competent response of children of different ages. Children of 3 years old could be considered sufficiently competent if they are able to recognize emotions, but by the age of 5 children would be expected to, additionally, behave in a socially accepted manner.

Our second aim was to study the developmental trajectories of the SEC profiles. In this regard, we noticed two interesting findings. Firstly, to our surprise, the probability of belonging to the 'prosocial' profile in the older children was not related to their previous SEC profile membership. Considering that prosocial responses in adults are driven partly by the understanding of others' emotions (Baston, Ahmad, Powell & Stocks, 2008), we expected that profiles that showed better emotional recognition would have higher probabilities to move into a prosocial profile. Although longitudinally we did not observe this expected transition, we did observe, at the profile level, that the combination of 'prosocial' behavioral responses went hand in hand with 'sad' and 'angry' emotional responses, which are indicative of adequate emotional recognition when facing conflictive situations. This finding suggests that there is a general natural maturational tendency of children to develop a prosocial attitude, as shown by Svetlova, Nochils, and Brownell (2010), who reported that the propensity to respond in a prosocial manner increased significantly from 18 to 30 months old. Secondly, we noted that children belonging to the 'Angry' profile—characterized mainly by angry responses—had the highest probability of transitioning to an aggressive profile, which is consistent with previous cross-sectional research, which showed that children who reported angry emotions present more aggressive behaviors (Denham et al., 2013; Strayer, & Roberts, 2004). However, it is noticeable that children that respond in an 'angry' manner are also considered to be able of recognizing emotions, which has been related as well with 'prosocial' behavior.

Finally, we aimed to explore the relations of hot and cool executive functions (EF) with socioemotional competence, and to ascertain whether this relation was bidirectional. Surprisingly, we did not find any significant relations between membership to SEC profiles and hot EF. This might have been caused by the ceiling effect in the hot EF task, which resulted in heavily skewed responses on the delay tasks and, consequently, in insufficient variance to capture the uni- and bidirectional relations we expected. The skewed distribution, however, may also be a reflection of the cultural dependency of hot EF tasks and, in particular, of the performance on the delay of gratification tasks. For example, Mexican children may be more compliant with adult instructions than Anglo-American children, which is subsequently reflected in their performance on the delay of gratification tasks. In fact, previous research on 8-year-old children found that Latina girls showed significantly more respect for parental authority than their European and American counterparts (Dixon, Graber, & Brooks-Gunn, 2008). Hence, it seems that social cues may indeed aid children's hot EF (i.e., ability to delay gratification); however, further research—using a more sensitive measure—is needed to test this idea.

We found a significant bidirectional relation between cool EF (inhibitory control) and SEC profiles in our older groups (4 to 6 years old). As expected, our model showed that performance in inhibitory control decreases the probability that children end up in an aggressive profile later on. These results ratify the central place of inhibitory control as a pillar for children to behave in a socially accepted manner. As reported previously by Rhoades, Greenberg, and Domitrovich (2009), and by Huyder and Nilsen (2012), inhibitory control assists children in suppressing inappropriate behaviors—like aggressive behavior—and favor more collaborative conduct instead. More importantly, beyond the developmental trend to improve inhibitory performance by age, SEC profile membership at age four predicted children's performance in inhibitory control by age five. Children whose responses reflected poorer emotional recognition—i.e., 'Mostly happy' profile—had a higher probability of performing low in the next assessment of inhibitory control. Moreover, children with better emotional recognition, as shown in the profiles 'Sad & angry' and 'Angry', were more likely to have a better inhibitory performance subsequently. At first sight, these findings involving the 'Angry' profile seem to be contradictory. On the one hand, it is the profile with the highest probability to transition to an 'aggressive' profile; and on the other hand, it is also one of the profiles more likely to have a better inhibitory performance. Although this may seem contradictory, 'angry' responses are also considered a sign of emotional recognition (as a child reacting angrily to a socially disruptive situation may be adequate). Additionally, both profile membership and the transition among profiles, are based on probabilities, so they are not deterministic. It may be that the levels of inhibitory control moderate the transition to an aggressive profile. In other words, children with a high inhibitory control may compensate the reported angry feelings and may be able to avoid turning these into an aggressive response. These results provide further support to the notion of a critical window of opportunity for interventions in the prevention of aggressive behaviors in young children, supporting in this way successful programs like 'The Incredible Years' (Webster-Stratton, 2005). Children who display a tendency to manifest anger in their early years may be timely guided on how to handle these emotions and respond to them in a socially accepted manner.

Unfortunately, we could not make a comparison between our findings and those from Ferrier and colleagues (2014) as the conceptualizations of executive functions and the elements of socioemotional competence included in both studies are different. However, both studies support the two-way relation existing between EF and different elements of SEC in young children, which may be a reflection of the wide gamma of aspects involved in the relation between EF and SEC. Finally, our findings expand the understanding of the relation between SEC and EF in at least two ways: first, whereas previous research has focused mainly on the emotion regulation component of emotional development in relation with executive functions (Carlson & Wang, 2007), our results highlight the role of emotion recognition in the development of executive functions, particularly inhibitory control. Second, our findings provide empirical, longitudinal evidence supporting theoretical models that propose a bidirectional relation between SEC and EF.

4.4.1 Limitations

To retain interpretability and feasibility of statistical analyses, we utilized information of only three time points with a one-year lapse between assessments. As young children develop at an accelerated pace, changes may occur in a shorter lapse of time, and a one-year period, therefore, could hide or diminish some of the relations we aimed to study. Although this represented a loss of valuable information, the included time points in our view sufficiently captured the behavior of interest. A second limitation is that in order to test the direction of the relations we recoded inhibitory control and delay of gratification into categorical variables, which resulted also in a loss of information and a reduction of variance. The final limitations refer to the measurements utilized. On the one hand, we encountered severe ceiling effects in the delay of gratification tasks. Even though the Preschool Self-Regulation Assessment (PSRA) battery has been widely used—also on children with a Latin background—these tasks had a highly non-normal distribution in our sample, which could have affected our results. On the other hand, the Challenging Situation Task-R—the instrument we used to assess SEC—presents a male transgressor in all the situations, and this could have biased the responses of girls and boys to the situation.

4.4.2 Implications for practice and further research

With this study, we have contributed to deepening the existing knowledge about the development of SEC in young children. Our results might be particularly relevant to raise awareness about the way we conceptualize SEC under a specific cultural context and developmental moment. We encourage other developmental researchers to approach SEC in a person-centered manner, based on direct child assessments, and following a descriptive approach. For teachers and policymakers, this information may shape a more precise guidance to provide better support for children to acquire the developmentally appropriate SEC skills.

More importantly, we found a bidirectional relation between SEC and cool EF (inhibitory control). In agreement with Ferrier and colleagues (2014), we plead that social and emotional competence, as well as cognitive development (like EF), should be considered in early childhood education programs. As urged by the National Scientific Council on the Developing Child (2004) “all early childhood programs […] must balance their focus on cognition and literacy skills with significant attention to emotional and social development” (p. 4), we aspire that the current study helps move the field towards a more integrative approach of developing children that simultaneously promotes diverse aspects of their development.

Chapter 5

GENERAL DISCUSSION

The general aim of the EDIP project (*Estudio del Desarrollo Integral del Preescolar*) was to explore the development of Mexican young children from a multidimensional perspective. We investigated the development of executive functions, pre-academic skills, motor skills and socio-emotional competence across the early childhood education period, as well as the concurrent and longitudinal interrelations among them. Based on the high interconnection between developmental domains characteristic of the early childhood years (Snow & van Hemel, 2008), we argued that a multidimensional study of child development could clarify ways in which we can help children develop in a synergetic manner. In this final chapter, we summarize and integrate the main findings driven by the empirical studies. We reflect on the limitations of this project and provide some suggestions for future research, and finally, we discuss the implications for practice.

5.1 Summary of main findings

Chapter 2 focused on determining the factorial structure and assessing the measurement invariance of three of the domains under study: executive functions, pre-academic skills, and motor skills. We sought to achieve an appropriate representation of the constructs across age and early childhood education (ECE) grades, as invariance is a critical assumption in developmental research. For the three domains, we tested factor structure models that are usually proposed in the early childhood literature. We found that a single factor structure was the best way to depict pre-academic skills, including tasks of early numeracy and early literacy. Likewise, a single factor structure was selected to represent executive functions, including tasks of inhibitory control and working memory. For motor skills, a two-factor model, consisting of fine and gross-motor skills was selected. Additionally, we tested three levels of invariance: configural (same factor structure), metric (same loadings) and scalar (same thresholds or means). We did so in a cross-sectional design—including three early childhood education grades (ECE1, ECE2, and ECE3)—and in a longitudinal design—including six time points. Interestingly, none of the three developmental domains achieved full configural invariance. Partial configural invariance was achieved only after trimming the developmental range we explored: for pre-academic skills by including only the last ECE grades or excluding the first time point; for executive functions by including only the last ECE grades or only time 3 and 5, and for motor skills including only the first four time points. Metric invariance was achieved for executive functions in the cross-sectional design—including ECE2 and ECE3, for pre-academic skills in the longitudinal design—including time 3 and 4, and for motor skills on the longitudinal design—including time 1 to time 4. None of the domains achieved scalar invariance.

Chapter 3 and Chapter 4 explored the longitudinal relations between developmental domains. Figure 5.1 shows the relations that were explored in both of these chapters, with blue arrows representing the relations explored in Chapter 3, and grey arrows representing the relations explored in Chapter 4.

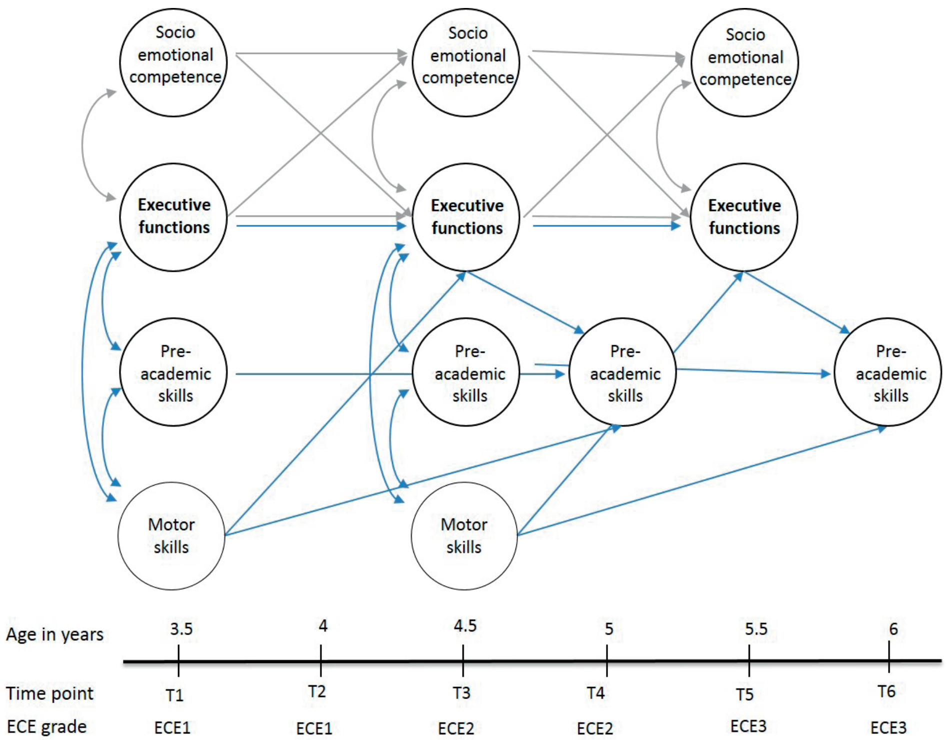

Figure 5.1. Interconnections explored in the empirical studies of the EDIP project. *This figure is an integrative representation of the studies conducted; it does not reflect the accurate SEM models that were tested.

In Chapter 3, we explored the relation between motor skills and pre-academic skills, and the mediating role of executive functions in that relation (see blue arrows in Figure 5.1). Although theoretically executive functions have been placed as a central pivotal point in the relation between motor skills and pre-academic skills, further empirical exploration is needed to resolve the possible mediator role of executive functions in young children. Given the lack of invariance in these constructs across the full age range the sample (see Chapter 2), we separated the children in two groups, a younger cohort—including children from 3.5 to 5 years old, and an older cohort—including children from 4.5 to 6 years old. For both groups, we found a significant, positive, strong relation between motor skills and executive functions, and between executive functions and pre-academic skills. Regarding the mediation, we found that in the younger group—unlike the older group—the relation between motor skills and pre-academic skills was only present via the mediation effect of executive functions; that is, a full mediation effect, even after controlling for baseline performance and relations. In the older group, the full mediation effect of executive functions on the relation between motor skills and pre-academic skills faded when including baseline performance and relations.

Finally, in Chapter 4 we explored the development of socioemotional competence and its potential bidirectional relation with hot and cool executive functions (see gray arrows in Figure 5.1). We adopted a person-centered approach to capture the development of socioemotional competence,—by means of latent class analysis—so as to detect typical combinations of children's emotional and behavioral responses to social conflictive situations. We did so in three different time points: at, on average, 3.5, 4.5 and 5.5 years of age. Different socioemotional profiles were identified. At 3.5 years old we identified four profiles, which differed mainly in their emotional responses: 'Mostly happy', 'Happy-sad-angry', 'Angry' and 'Sad'. At 4.5 years old we identified five profiles: 'Mostly happy', 'Happy-sad-angry', 'Angry', 'Sad-angry' and 'Sad'. Although the profiles at this age also differed mainly in the emotional responses, the behavioral responses started to play a role in the differentiation of the profiles. At 5.5 years old we identified four profiles, which were more clearly differentiated in their combination of both emotional and behavioral responses: 'Mostly happy', 'Angry-sad & aggressive', 'Sad-angry & avoidant' and 'Sad-angry & prosocial'—with the 'Sad-angry & Avoidant' profile being the most frequent. Based on these profiles, we conducted an Associative Latent Transition Analysis to test the bidirectionality of the relation between socioemotional competence and hot and cool executive functions. Contrary to our expectations, we found no evidence of a significant relation of socioemotional competence with hot executive functions. The proposed bidirectionality was attested only with cool executive functions, and only at a later developmental stage (from 4.5 to 5.5 years old). Performance in cool executive functions (inhibitory control) at age 4.5 was related with the socioemotional profile membership of children at 5.5 years old. For example, children who performed high in cool executive functions had a lower probability of belonging to the profile 'Angry-sad & Aggressive' in comparison with low performers. We also observed a significant relation between the membership to a socioemotional profile at 4.5 years old and children's performance in cool executive functions at age 5.5. For example, children of 4.5 years belonging to the 'mostly happy profile'¬—i.e., children that respond that they would feel happy under challenging social situations—had the highest probability to have low performance in cool executive functions at age 5.5. These children are almost five times more likely to be among the low performers in cool executive functions than children in a 'Sad & Angry' profile.

5.2 Integrative findings

"The path of development is a journey of discovery that is clear only in retrospect, and it is rarely a straight line"

Kennedy-Moore & Lowenthal (2011, p.3)

5.2.1 Development of the domains

If one thing is clear after conducting the EDIP project is that the development of young children is an amazing roller coaster, and one that is far from linear. First, we noticed a constant fluctuation between 'unity and diversity' across our developmental domains. The tension between unity and diversity was described by Miyake and colleagues (2000) when they explored the dimensions of executive functions in young children. We observed degrees of unity and diversity in all developmental domains, both at a domain level and at a child level. At a domain level, for example, we noted that at a determined point in time, executive functions and (in some cases) pre-academic skills, were equally well represented by a unique factor or by two related but distinct factors. This differs from what we observed in the development of motor skills, as this domain seemed to start from a more integrated construct, followed by a higher differentiation as children grow older. At the child level, for example, we observed that the distribution of children allocated to the different profiles was equitable in the first grade (ECE1), whereas in the third grade (ECE3) the majority of the children were allocated to one particular profile, reflecting thus more diversity in an earlier period. It seems that the ratio between unity and diversity is time- and construct-dependent, rather than responding to a fixed pattern. Maybe this is the reason why multiple studies operationalized the constructs in different manners; some supporting generic structures and others more differentiated constructs.

Second, we observed what we could call a heterotypic continuity in some of the developmental domains we studied. The term heterotypic continuity was utilized by Petersen and colleagues (2016) to describe the development of inhibitory control. With this term, the authors expressed that although there is a continuous underlying process or function in the development of a skill, the manifestations of that skill diverge at different developmental moments. In our study, we argued that this attribute might also apply to the development of motor skills and socioemotional competence. Regarding motor skills, we indeed observed that as children grow older, the representation of the construct becomes more complex and some tasks become obsolete. This signifies the need for more age-specific tasks to measure an increasingly more differentiated skill. Signs of heterotypic continuity were also detected in the differentiation of the profiles of socioemotional competence. For example, profiles in the first grade (ECE1) were mainly differentiated by their emotional responses, whereas in the third grade (ECE3) the differentiation between profiles consisted mainly of a combination of emotional and behavioral responses.

Finally, although it may seem that given such heterotypic continuity and the associated changing characteristics that are inherent to the developmental nature of the early childhood period, an invariance analysis might be perceived as paradoxical. However, in our view, it is precisely because of the rapid, non-linear and dynamic development that invariance analysis is not only important in light of the assumptions of typical statistical techniques, but is a rich source of information about such non-linear and dynamic development on itself. Therefore, the analysis of invariance should not be conducted solely for the sake of reaching invariance, but as an exploratory step that yields critical insights into the way development occurs, and therefore, as an important step to inform posterior analytical decisions and interpretation of results—and consequently, to inform developmental theory.

5.2.2 Interconnections among domains

The inconsistent (also referred to as nonlinear, unstable, disharmonic, heterotypic or asymmetric) way in which the domains develop has an impact on their relations. As noted by Snow (2007), the different developmental trajectories of a set of child skills may or may not intersect. We observed this ‘developmental convergence’ in both of our relational studies. In the case of executive functions and socio-emotional competence (Chapter 4), the expected bidirectional relation was present only when the children were relatively older—from 4.5 to 5.5 years old. On the contrary, the mediated role of executive functions (Chapter 3) was observed only in our ‘younger’ group (from 3.5 to 5.5 years old), whereas in the 'older' group this mediation faded when controlling for baseline performance and concurrent relations. Together these findings support the need to explore developmental interconnections within multiple windows of time and not only on an aggregated level, as important information may be hidden, faded, or even enhanced in a certain developmental moment.

Figure 5.2 depicts and abstract illustration of the fluctuating development of five domains (green, blue, red, pink and purple lines), and three assessment points: A, B, and C. A researcher focusing on time point A may conclude that the domains are highly interconnected. If time points A and B are included, then the researcher could conclude that there is a high interconnection at a younger stage, but the relations lose strength and possibly become negligible at a later stage. Nonetheless, if time point C is explored, the conclusions will be similar to those drawn at time point A. In this sense, a researcher who observes only time points A and C will conclude undoubtedly that there is a high interconnection between the domains and that they develop together. Such conclusion, however, overlooks the changes occurred between times A and C. Moreover, if we take the time points A and B, the domain depicted in purple shows important growth, whereas slight change is observed in the green domain, and relative stability is observed in the blue and red domains. Additionally, we can see that some developmental domains—like the blue and the pink one—develop more stably, whereas others—like the purple and green domains—highly fluctuate during their development. Finally, other domains, like the red one, may show an accelerated development in a certain period followed by a moment of stability. In the special case of the blue domain, as much as it seems to develop in a relatively steady manner, the line shows a change in color over time (from dark blue to light blue) that represents its heterotypic nature. If this intrinsic heterotypic change is not properly captured by the measurements utilized, the resulting developmental trend may be misleading. Although this figure is an abstract representation, it allows to exemplify clearly the developmental fluctuations and convergence that we discussed in the previous sections.

Finally, in this project, executive functions were placed central and studied as an anchor that connects different developmental domains, i.e., as a bidirectional influence between executive functions and socioemotional competence, and as a mediational influence of executive functions in the relation between motor skills and pre-academic skills. Furthermore, it has been proposed that the key to improving executive functions is not to focus solely on them, but to simultaneously address other developmental domains, such as children's socioemotional development, or their

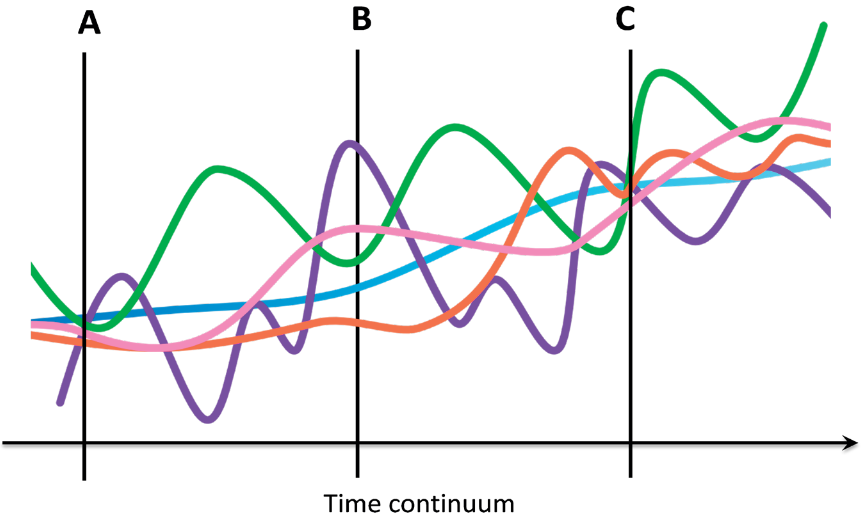

Figure 5.2. Developmental fluctuation and convergence

physical and motor skills (Diamond & Lee, 2011; Zelazo, Blair, & Willoughby, 2016). In our view, the close developmental interrelation present in the early childhood years—particularly with executive functions—can be used to create and facilitate a developmental synergy, in which advances in one domain are reflected in another domain. On the one hand, domains like motor skills or socioemotional competence can influence the development of executive functions, and on the other hand, executive functions can aid in the development of socioemotional competence and pre-academic skills. From this perspective, and based on the central developmental role of executive functions, it is plausible, for example, that by stimulating the motor skills of children at age 3 we might enhance the executive performance at age 4, which may impact on the way children handle conflictive social situations at the age of 5. Such hypothetical yet plausible developmental synergy, underscores the notion that child development is a system of interrelated domains, implying that different intervention paths are possible in order to foster it.

5.3 Limitations and methodological considerations

There are several general limitations that concern the project as a whole, besides the study-specific limitations that were discussed in Chapters 2 thru 4. These general limitations are closely associated with methodological considerations and decisions made throughout the project.

Firstly, despite our efforts of using well-established tests, the selection of instruments and measurement of the constructs represented a challenge from the design of the research for three reasons:

(a) the availability of tests that were validated in a Mexican, or Latin American context (or available in Spanish—the language spoken in Mexico) was limited.

(b) the target age span of 3 to 6 years old posed challenges, as most tests that have been designed to address early childhood children cover the developmental period between 4 to 6 years old. Only a few tests cover the developmental period of 3 to 6 years old—the age range of mandatory early childhood education in Mexico.

(c) the severe floor or ceiling effects encountered in at least one task of each domain, which led to the restriction or even elimination—in the case of delay of gratification tasks—of test information.

Nevertheless, we counterbalanced this limitation by employing different analytical approaches. For example, we split the sample in a 'younger' group and an 'older' group, and we equated the scores of the motor skills tasks to create a continuum for tasks that had different degrees of difficulty for younger and older children. Additionally, we carefully considered the operationalization of the constructs to ensure their proper representation for each developmental time period.

Secondly, we used an accelerated longitudinal design, which added an extra level of complexity to the already inherent challenges of a longitudinal design (e.g., attrition, issues related to measurement invariance, or test-retest learning effects). For example, the large amount of missing information caused by the accelerated design added uncertainty to the analysis. Additionally, the analytical procedures—already complex ones—become more complex by the use of multiple imputed datasets. In fact, even if missing data were handled with Full Information Maximum Likelihood, the large amount of missing data would result in problems with convergence in these complex models. However, we recognized that this design has substantial advantages and that the modern techniques for handling missing information reduce the uncertainty introduced by the accelerated design to a minimum. Maybe this kind of design is more useful in a developmental moment when the participants are in a more stable period. Furthermore, for this longitudinal study, we planned a biannual assessment of the children and as a result, we had six time windows in a three-year-period. In our view six months was a time lapse that was large enough to capture growth and development, but close enough to capture developmental fluctuations inherent to this period while also considering research constraints—e.g., resources, time, and test-retest effects. Whether or not a six-month-period is an optimal time lapse in a longitudinal study addressing young children may be debatable, but in our opinion, it was a good compromise of theoretical and pragmatic considerations.

Thirdly, the conceptualization and operationalization of the constructs. We have made enormous efforts to achieve a proper representation of the constructs, but these also affected subsequent analytical and methodological decisions. On the one hand, our desire to express socioemotional competence from a person-centered approach implied that all further analyses were based on a categorical distinction rather than on continuous variables. In this sense, a latent class analysis, and the corresponding associative transition analysis, were needed to explore the bidirectional relation between socioemotional competence and executive functions. In addition, because of the analytical strategy we had to transform other constructs such as 'cool' and 'hot' executive functions also into categorical variables, which may have resulted in a loss of variability in the construct. On the other hand, as we used a relatively robust longitudinal design (with six time points) sadly, we could not utilize the complete data set, mainly due to the lack of a common factorial structure that applied equally to the age range of our sample. The limited measurement invariance forced us to explore different operationalizations of the constructs and alternative ways of analyzing them. Whereas nowadays there is a vast set of applications and examples of longitudinal modeling (see for example Little, 2013), the assumptions required for these kinds of models are not easily met. As much as these novel techniques are appealing and tempting to researchers, awareness needs to be raised about the assumptions and requirements for the use of such models, such as measurement invariance. In our project, the lack of measurement invariance limited our modeling possibilities. For instance, Chapter 4 would have required a common factor structure for three different domains (executive functions, pre-academic skills, and motor skills) to test a full longitudinal mediation model, whereas, in practice, only a simplified version of the mediation model was viable.

Finally, a fourth limitation concerns the exclusion of other important developmental domains and covariates. In our study, we aimed for a multidimensional perspective of child development, but we are aware that our study did not cover other important developmental domains like intelligence, or contextual factors like the school and family environment, or other additional covariates, like general health indicators. Nonetheless, in our study, we focused on key developmental domains in early childhood, and we explored their development and interconnectivity.

5.4 Recommendations for future research

Based on the methodological challenges that we faced in this project, we recommend future researchers:

Firstly, to consider the inclusion and revision of instruments that have been shown to be developmentally sensitive and appropriate for the age period of interest. We argue that the ideas presented by Petersen and colleagues (2016) may be a good alternative to tackle issues related to measurement invariance and floor or ceiling effects. They suggested the use of distinctive measures that reflect the particularities of a certain period, and the application of overlapping measures that may be used as a developmental bridge to connect different periods, especially in domains that show heterotypic continuity. We think that this approach may help to better capture the development of the domains. Additionally, there has been an increasing effort in the field to develop instruments that are sensitive, multidimensional and validated in different populations. For example, the International Development and Early Learning Assessment (IDELA) developed by the Save the Children foundation, has shown strong psychometric properties and has been validated in different populations (including Latino countries) and it is available publicly in a Spanish version. We encourage future researchers to use tools with these characteristics, as an initial step in the effort to achieve a proper evaluation and representation of developmental domains in young children.

Secondly, to explore whether the expected structure is reflected in all of the domains that are targeted and to describe thoroughly the methodological procedures and decisions. We invite developmental researchers to pay attention not only to the selection of appropriate instruments, but also to how to best represent their constructs. Independently of the use of “well-known” tests, the exploration of the equivalence of the measures should be considered a basic first step for every analytical approach that utilizes latent constructs. Moreover, if researchers report more thoroughly the methodological challenges they encountered—e.g., how the representation of the constructs was established and the system employed to score the tests scoring approach that was followed—other researchers can benefit from this knowledge when designing and conducting their own projects. Nevertheless, we are aware that the space limitations in academic journals and the publish-or-perish culture in the academic world may prevent researchers to explicitly and elaborately state all their methodological considerations. Therefore, we consider it important that they take advantage of, for example, the possibility offered by many journals to add electronic supplementary materials with these details.

Finally, to use alternative methodologies to explore and portray development. We would like to point to two alternative methodologies to explore and represent the development of the domains, particularly in young children. For example, the use of mixed models—like a person-centered approach—may offer a rich source of distinctive and complementary information to the traditional variable-centered approaches (Masyn, 2013). Another option is the adoption of complex dynamic systems, as they allow to flexibly represent development, by not assuming linearity and by embracing variability as an inherent property of development (Larsen-Freeman, 1997). In both cases, there are methodological implications that have to be weighed when selecting them, and the use of one or the other—or any methodology, for that matter—should be theory-driven.

5.5 Practical implications

This project helped to enlighten how key domains develop and the way they interconnect in the early childhood period of Mexican children. We consider such research vital for two principal reasons: first, because there is an undeniable academic crisis in Mexico and executive functions may work as a compensatory tool, and second, because there is an increasing recognition on early childhood education about the need of conceptualizing the developing child as a whole, giving equal importance to all developmental domains and not only the cognitive sphere. Although these reasons seemed to be contradictory, they are in fact complementary, as improvements in academic achievement can happen as a natural consequence of an integrative and multidimensional development of the children, in what is called a developmental synergy.

About the first reason, previous research has pointed out that well-developed executive functions serve as a protection against academic failure related to low socioeconomic status and adversity (for a review see Zelazo, Blair, & Willoughby, 2016). Therefore, in countries like Mexico adopting an early approach of a multidimensional development—influencing, therefore, the development of executive functions from different sources—may have a compensatory effect and could help to close the educational lag.

More importantly, a better understanding of how key developmental domains—including executive functions—develop in the early years and how they are interconnected—exploring when and how they are presented—could help to better channel strategies to support an integral development. In fact, as proposed by UNICEF (2012) a holistic view on the development of children requires not only that children get ready for school in various developmental areas, but also that it is essential to ensure that schools and families are ready for the multidimensionality of the developing children. Our results provide empirical evidence for the relevance of examining child development with a multidimensional approach. Teachers, policymakers and parents could benefit from these results by (a) providing information about the developmental characteristics and needs within specific developmental moments, and (b) by raising awareness about the need for a balance in the attention that is given to each developmental domain. For example, whereas considerable efforts are made in teaching children to count and read, comparatively less attention is paid to guiding them in the recognition and management of their emotions. Furthermore, parents are frequently stimulated to read together with their children, but comparatively they receive little guidance on how they could promote motor development.

With this project, we hope to have raised awareness of the importance of a multidimensional approach to child development. By doing so, aid future researchers, policymakers, teachers, and parents to be better able to guide children in an age-appropriate manner while keeping in mind the multidimensional and interconnectedness of core developmental domains.

addendum

APPENDICES

Appendix A

Imputation process

The imputation process was realized using the Multivariate Imputation by Chained Equations (MICE) package in R (Van Buuren & Groothuis-Oudshoorn, 2011). The prediction matrix for the imputation was established based on the correlation matrix of the complete data set. A minimum correlation of r = .30 was required for a variable to be included as a predictor of another variable. Additionally, demographic variables—i.e., cohort, sex, school, mother educational level, and monthly income—were included as predictors regardless of the strength of correlations. We used the default imputation method (predictive mean matching) to impute five data sets, based on the suggestions of Van Buren (2012), who stated that it is unlikely that the substantive conclusions will change by adding more than five datasets.

Quality checks of the imputed data—based on diagnostic plots and ANOVAs between the observed and the imputed data sets—showed the need to improve the imputation model for socioemotional variables. We did this by adding the full span of socioemotional responses (from time 1 to time 6) as predictors. The rest of the variables remained with the same prediction model as initially described. This second round of imputation yielded better imputation values of the variables and was taken as the final solution. All further analyses were conducted using this multiply imputed data set.

Appendix B

Factor loadings for the final selected models per domain

Domain	Task	Cross-sectional				Longitudinal						
		General	ECE1	ECE2	ECE3	General	T1	T2	T3	T4	T5	T6
Pre-academic skills	Picture vocabulary	.48		.59	.54	.78		.55	.51	.55	.37	.54
	Letter-word id	.56		.56	.53	.77		.47	.57	.55	.74	.72
	Applied problems	.76		.85	.78	.87		.77	.82	.81	.66	.47
	Quantitative concepts	.81		.73	.85	.81		.76	.73	.70	.44	.65
Executive functions	Day-night	.43		.29	.35				.35		.35	
	Angel-devil	.56		.25	.25				.35		**.15**	
	Blocks backwards	.72		.60	.50				.64		.57	
	Digits backwards	.75		.66	.94				.69		.76	
Motor skills [a]	Posting coins	.61	.58			.75	.53	.46	.42	.51		
	Threading beads	.75	.53			.73	.60	.79	1.1	.99		
	Drawing trail	.78	.64			-.45	.62	.52	.47	.29		
	Catching	.51	**.15**			.14	**.14**	.32	.32	.24		
	Throwing	.53	.42			.67	.33	**.13**	**.15**	**.08**		
	One-leg balance	.56	.36			.69	.28	.25	.44	.39		
	Walking line	.62	.66			.51	.72	.69	.39	.57		
	Jumping mats	.36	.28			.12	**.11**	.22	**.20**	.31		
	r's	.83	-			.72	.80	.54	.42	.35		

Note. [a] Loadings for motor skills are based on a two factor model (version B) separated by a line: fine motor skills on the top and gross motor skills on the bottom; except for the factor loadings of motor skills for ECE1 (marked in gray) which are based on a single-factor model.

Non-significant loadings are bold-marked.

Appendix C

Quality of classification of the socioemotional profiles

	Entropy	Class *k*	Estimated proportion	McaP	AvePP	OCC
Time 1	.91	C1.1	.32	.32	.93	29.79
		C1.2	.23	.23	.98	216.16
		C1.3	.24	.24	.96	94.23
		C1.4	.20	.20	.94	63.79
Time 3	.88	C3.1	.09	.09	.94	151.19
		C3.2	.15	.16	.90	48.32
		C3.3	.24	.22	.93	42.26
		C3.4	.37	.37	.89	15.02
		C3.5	.13	.13	.98	471.32
Time 5	.93	C5.1	.50	.50	.96	29.18
		C5.2	.31	.31	.95	42.20
		C5.3	.04	.04	1.00	*
		C5.4	.13	.13	.96	197.19

Note. McaP = Modal class assignment Proportion (values are expected to be as similar as the proportions estimated by the model); AvePP = Average Posterior class Probability, (values are expected to be close to 1); OCC = Odds of Correct Classification (to be considered an adequate separation values are expected to be higher than 5 in all classes of the model). Based on Masyn (2013).

A

Appendix D

Frequency of responses per socioemotional profile

Average frequencies of emotional and behavioral responses per Socioemotional profile

Time	Profile	Emotional responses*			Behavioral responses*		
		Angry	Sad	Happy	Avoid	Aggressive	Prosocial
1	C1.1	.15	.24	5.51	2.49	.96	1.87
	C1.2	1.12	1.37	2.87	2.00	1.24	1.97
	C1.3	3.25	.97	.48	2.44	1.21	1.53
	C1.4	.53	4.19	.71	2.14	1.16	1.71
3	C3.1	.11	.25	5.38	2.80	.40	2.56
	C3.2	1.39	1.35	1.96	1.97	1.38	2.14
	C3.3	4.80	.34	.12	2.02	1.90	1.78
	C3.4	2.18	2.58	.30	2.37	.77	2.29
	C3.5	.35	5.15	.29	2.48	.68	2.42
5	C5.1	.30	.04	4.97	2.57	1.09	2.31
	C5.2	2.42	1.86	.46	1.39	2.74	1.70
	C5.3	1.70	2.45	.31	3.83	.20	1.70
	C5.4	1.42	3.22	.29	.91	.19	4.77

Note. *Estimated average frequency out of a total of six situations.

SAMENVATTING
(DUTCH SUMMARY)

Tijdens de vroege kinderjaren ontwikkelen kinderen snel in motorische, cognitieve en sociale vaardigheden (UNESCO, 2014). Deze periode wordt gekenmerkt door een intensieve hersenontwikkeling en cognitieve ontwikkeling, een versnelde fysieke en motorische ontwikkeling en ze wordt beschouwd als de meest geschikte periode in de ontwikkeling om sociale vaardigheden te leren (Denham et al., 2013; Kuther, 2016; UNESCO, 2014; Zelazo, Qu, & Kesek, 2010). In dit onderzoeksproject hebben we ons gericht op de periode van de vroege kinderjaren waarin kinderen 3 tot 6 jaar oud zijn. Op het gebied van het jonge kind is recentelijk de noodzaak benadrukt om de dynamische ontwikkeling van kinderen te omarmen en betoogd dat ontwikkelingsdomeinen moeten worden onderzocht in samenhang en niet als gescheiden domeinen (Snow, 2007; Snow & van Hemel, 2008; UNESCO, 2014).

Het huidige onderzoeksproject is opgezet om de ontwikkeling van jonge kinderen vanuit een multi-dimensioneel perspectief te bestuderen door de ontwikkeling van en interacties tussen verschillende vaardigheden en functies van centrale ontwikkelingsdomeinen te onderzoeken, te weten: pre-academische vaardigheden, motorische vaardigheden, executieve functies en sociaal-emotionele competentie.

Pre-academische vaardigheden. Pre-academische vaardigheden zijn vaardigheden die van fundamenteel belang zijn voor lezen, schrijven en rekenen. Door beginnende geletterdheid verwerven kinderen de basiskennis en schriftelijke en mondelinge vaardigheden—zowel het decoderen als coderen—, en attitudes die nodig zijn voor lezen en schrijven (Storch & Loningan, 2002; Whitehurst & Lonigan, 1998). Door beginnende rekenvaardigheid ontwikkelen kinderen de voorbereidende vaardigheden voor complexere rekenopgaven, zoals tellen, numerieke relaties en rekenkundige bewerkingen (Purpura, Hume, Sims, & Lonigan, 2011; Raghubar & Barnes, 2017).

Motorische vaardigheden. Traditioneel wordt er een onderscheid gemaakt tussen grove en fijne motorische vaardigheden. Grove motorische vaardigheden hebben betrekking op het gebruik van grote spieren voor evenwicht, oriëntatie en de beweging van romp en ledematen. Fijne motorische vaardigheden zijn nodig voor de coördinatie van kleine spieren om motorische precisie en integratie te bereiken (Cameron, Cottone, Murrah, & Grissmer, 2016; Van der Fels et al., 2015).

Executieve functies. Executieve functies zijn hogere controlefuncties van de hersenen die gebruikt worden voor de beheersing van gedachten en acties (Carlson, 2005). Bij jonge kinderen zijn er twee onderling samenhangende subdomeinen te onderscheiden: inhibitie en werkgeheugen (Lerner & Lonigan, 2014; Miller et al., 2012; Karalunas, Bierman, & Huang-Pollock, 2016). Inhibitie verwijst naar het vermogen om primaire reacties te onderdrukken en een alternatieve reactie te kunnen geven. Werkgeheugen verwijst naar het vermogen om informatie te decoderen en coderen, en de verwerking van die informatie te controleren (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Daarnaast wordt er een onderscheid gemaakt tussen zogenaamde 'warme' en 'koude' executieve functies. Warme executieve functies omvatten affectieve en motiverende verwerking en vereisen constante evaluatie van de affectieve waarde van de stimuli. Koude executieve functies worden gebruikt voor de omgang met abstracte gedecontextualiseerde problemen (Zelazo & Müller, 2002).

Sociaal-emotionele competentie. Sociaal-emotionele competentie bestaan uit een set van sociale en emotionele vaardigheden die onlosmakelijk met elkaar verbonden zijn. Deze vaardigheden omvatten het vermogen om positieve relaties met anderen te ontwikkelen, op een prosociale wijze te handelen en het vermogen om emoties op een culturele en sociaal passende wijze te herkennen, te reguleren en uit te drukken (Campbell et al., 2016; Camras, Shuster, &n Fraumeni, 2014).

Het algemene doel van het onderzoeksproject *Estudio del Desarrollo Integral del Preescolar*: EDIP (Studie van de integrale ontwikkeling van kleuters) was het verkennen van de ontwikkeling en de relaties tussen meerdere ontwikkelingsdomeinen bij jonge Mexicaanse kinderen van 3 tot 6 jaar oud. Gezien de versnelde en niet-lineaire ontwikkeling van jonge kinderen, zijn de stabiliteit en gelijkheid van de factorstructuur van drie centrale basisdomeinen onderzocht op verschillende momenten in de ontwikkeling (hoofdstuk 2). Om het integratieve beeld van de ontwikkeling van het kind te verbreden hebben executieve functies een centrale rol in dit project en vormen ze de basis die de verschillende ontwikkelingsdomeinen met elkaar verbindt en beïnvloedt: aan de ene kant als mediator in de relatie tussen motorische en pre-academische vaardigheden (hoofdstuk 3) en anderzijds in een wederzijdse relatie met sociaal-emotionele competentie (hoofdstuk 4).

Hoofdstuk 2: Meetinvariantie en vroege kinderjaren

In deze studie zijn de stabiliteit en gelijkheid onderzocht van de latente constructen die pre-academische vaardigheden, executieve functies en motorische vaardigheden vertegenwoordigen. Ook hebben we ons verdiept in het spanningsveld tussen de methodologische noodzaak van het hebben van invariante constructen en de grote veranderingen die inherent zijn aan dit ontwikkelingsstadium. Eerst hebben we de factorstructuur van elk domein onderzocht op basis literatuur over bekende structuren in de vroege kinderjaren. Daarna hebben we onderzocht of dezelfde structuur standhield in een cross-sectioneel en longitudinaal design. Het cross-sectionele design omvatte de drie leerjaren van vroegschoolse educatie in Mexico: ECE 1 (van 3 tot 4 jaar), ECE 2 (van 4 tot 5 jaar) en ECE 3 (van 5 tot 6 jaar). Het longitudinale design omvatte twee metingen per schooljaar op in totaal zes momenten. We vonden dat, in het algemeen, een factorstructuur met één factor de beste manier was om pre-academische vaardigheden en executieve functies weer te geven. Voor motorische vaardigheden werd een tweefactormodel gevonden, waarin fijne en grove motorische vaardigheden konden worden onderscheiden. Verder werden drie niveaus van invariantie getest: configuratief (equivalente factorstructuur), metrisch (equivalente ladingen) en scalair (equivalente drempels of gemiddelden). Geen van de domeinen bereikte volledige configuratieve invariantie. Gedeeltelijke configuratieve invariantie werd alleen bereikt na het versmallen van het ontwikkelingsbereik: voor pre-academische vaardigheden door alleen de laatste ECE-leerjaren (ECE2 en ECE3) mee te nemen, ofwel, door het eerste tijdstip uit te sluiten. Voor executieve functies door alleen de laatste ECE-leerjaren mee te nemen, ofwel, alleen meetmoment 3 en 5. Voor motorische vaardigheden door alleen ECE1 mee te nemen, ofwel, de eerste vier metingen. Bovendien werd metrische invariantie gedeeltelijk bereikt voor executieve functies in het cross-sectionele design; en voor pre-academische vaardigheden en motorische vaardigheden in het longitudinale design. Geen van de domeinen bereikte scalaire invariantie. Ten slotte hebben we betoogd dat het bereiken van ten minste configuratieve invariantie een verstandig compromis kan zijn tussen de striktheid van de statistische analysemethoden en de grote veranderingen in de ontwikkeling van jonge kinderen. Met dezelfde factorstructuur is het mogelijk om over meetmomenten (of leerjaren) de latente constructen gezamenlijk te modelleren, terwijl het ontbreken van andere niveaus van invariantie de ontwikkelingsverschillen van het construct in zich verenigt.

Hoofdstuk 3: Motorisch-cognitieve ontwikkeling van jonge kinderen

Hoewel executieve functies vanuit theoretisch perspectief gezien worden als het scharnierpunt in de relatie tussen motorische vaardigheden en pre-academische vaardigheden, is verder empirisch onderzoek nodig om de mogelijke mediërende rol van executieve functies bij jonge kinderen te verhelderen. Daarom hebben we in deze studie een mediatiemodel getest van executieve functies in de relatie tussen motorische vaardigheden en pre-academische vaardigheden. Dit hebben we gedaan in twee afzonderlijke cohorten: een ‘jonger’ cohort met kinderen van 3.5 tot 5 jaar oud, en een ‘ouder’ cohort met kinderen van 4.5 tot 6 jaar oud. Voor beide groepen vonden we een significante, positieve en sterke relatie tussen motorische vaardigheden en executieve functies, en tussen executieve functies en pre-academische vaardigheden. Wat betreft de mediatie vonden we dat in de jongere groep—in tegenstelling tot de oudere groep—de relatie tussen motorische vaardigheden en pre-academische vaardigheden alleen aanwezig was via een volledig mediatie-effect van executieve functies; zelfs na controle voor eerdere prestaties en relaties. In de oudere groep verdween het volledige mediatie-effect van executieve functies op de relatie tussen motorische vaardigheden en pre-academische vaardigheden wanneer voor eerdere prestaties en relaties werd gecontroleerd. Deze resultaten zijn in overeenstemming met Davids en collega's (2011) en ze ondersteunen het idee dat de motorisch-cognitieve relatie leeftijdsafhankelijk lijkt te zijn, omdat de verschillende vaardigheden zich met verschillende snelheden kunnen ontwikkelen en dus de manier beïnvloeden waarop de relaties tot uitdrukking komen.

Hoofdstuk 4: Sociaal-emotionele competentie en executieve functies

Deze studie had een tweeledig doel. Het eerste doel was om de ontwikkeling van sociaal-emotionele competentie te onderzoeken. Voor dat doel hebben we een persoonsgerichte benadering gekozen—door middel van latente klassenanalyse—om typische combinaties van emotionele reacties en gedragsreacties van kinderen op sociale situaties vast te leggen. Het tweede doel was om de relatie tussen sociaal-emotionele competentie en ‘warme’ en ‘koude’ componenten van executieve functies te onderzoeken. We verwachtten dat deze relatie mogelijk wederzijds was, in tegenstelling tot de vaak veronderstelde eenzijdige relatie. Verschillende sociaal-emotionele competentieprofielen konden worden geïdentificeerd. Op 3.5-jarige leeftijd identificeerden we vier profielen, die voornamelijk verschilden in de emotionele reacties. Op 4.5-jarige leeftijd identificeerden we vijf profielen. Hoewel de profielen op deze leeftijd ook voornamelijk verschilden in de emotionele reacties, begonnen de gedragsreacties een rol te spelen in de verschillen tussen deze profielen. Op 5.5-jarige leeftijd identificeerden we vier profielen, die duidelijker dan op de andere leeftijden gedifferentieerd waren in een combinatie van zowel emotionele als gedragsmatige reacties. Op basis van deze profielen hebben we de wederzijdse relatie van de sociaal-emotionele competentie met warme en koude executieve functies onderzocht. We hebben geen bewijs gevonden voor een significante relatie tussen sociaal-emotionele competentie en warme executieve functies. De verwachte wederzijdse relatie werd alleen gevonden voor koude executieve functies en in een later ontwikkelingsstadium (kinderen van 4.5 tot 5.5 jaar oud), maar niet in een eerder stadium (kinderen van 3.5 tot 4.5 jaar oud). Prestaties op koude executieve functies (inhibitie) op de leeftijd van 4.5 jaar waren gerelateerd aan het sociaal-emotionele competentieprofiel van kinderen op 5.5-jarige leeftijd. Kinderen die bijvoorbeeld hoog presteerden op koude executieve functies, hadden een kleinere kans om te behoren tot het profiel 'Boos-verdrietig & agressief' in vergelijking met laag presterende kinderen. We hebben ook een significante relatie gevonden tussen het sociaal-emotioneel competentieprofiel op 4.5 jaar oud en de prestaties van kinderen op koude executieve functies op 5.5-jarige leeftijd. Op 4.5-jarige leeftijd bijvoorbeeld, vertoonden kinderen in het 'meestal gelukkig' profiel—een teken van onontwikkelde emotionele herkenning—de grootste kans op lage prestaties in koude executieve functies op 5.5-jarige leeftijd. Ten slotte wijzen onze uitkomsten op de rol van emotionele herkenning bij de ontwikkeling van executieve functies, in het bijzonder inhibitie; en bieden deze empirisch bewijs ter ondersteuning van theoretische modellen die een wederzijdse relatie beschrijven tussen sociaal-emotionele competentie en executieve functies.

Slotopmerkingen

Dit onderzoekproject heeft een bijdrage geleverd aan het verduidelijken van de wijze waarop centrale ontwikkelingsdomeinen zich ontwikkelen en zich tot elkaar verhouden in de vroege kinderjaren van Mexicaanse kinderen. De nauwe relaties tussen ontwikkelingsdomeinen die aanwezig zijn in de vroege kindertijd—met name met executieve functies—kunnen worden gebruikt om een ontwikkelingssynergie te creëren. Enerzijds hebben domeinen als motorische vaardigheden of sociaal-emotionele competentie een belangrijke invloed op de ontwikkeling van executieve functies, anderzijds helpen executieve functies bij de ontwikkeling van sociaal-emotionele competentie en pre-academische vaardigheden. Een beter begrip van de ontwikkeling van deze centrale ontwikkelingsdomeinen en hun onderlinge verbondenheid—bijvoorbeeld door te onderzoeken wanneer en hoe deze worden ontwikkeld—kan helpen om meer richting te geven aan strategieën die de ontwikkeling van jonge kinderen stimuleren.

N

RESUMEN
(SPANISH SUMMARY)

Durante los primeros años de la infancia, los niños desarrollan rápidamente habilidades motrices, cognitivas y sociales (UNESCO, 2014). Este período se caracteriza por un desarrollo dramático cognitivo y cerebral, aunado a un acelerado desarrollo físico y motriz; se considera además como el momento apropiado de desarrollo para aprender habilidades sociales (Anderson, 2002; Denham et al., 2013; Kuther, 2016; UNESCO, 2014; Zelazo, Qu, & Kesek, 2010). En este estudio, consideramos el período de la primera infancia como el periodo que abarca desde los 3 a los 6 años. Expertos en primera infancia han enfatizado en la necesidad de adoptar una visión holística, interconectada y dinámica del desarrollo infantil, y han argumentado que los dominios del desarrollo deben investigarse en combinación y no como entidades separadas (Snow, 2007; Snow & van Hemel, 2008; UNESCO, 2014). En consecuencia, el presente proyecto de investigación se propuso estudiar el desarrollo de los niños pequeños de manera multidimensional e integradora, explorando el desarrollo y las interacciones de diferentes habilidades y funciones de los dominios clave del desarrollo: habilidades pre-académicas, habilidades motrices, funciones ejecutivas y competencia socioemocional.

Habilidades pre-académicas: se refiere a las habilidades básicas e interrelacionadas que son fundamentales para la lectura, la escritura y el rendimiento matemático. A través de la pre-literacidad los niños adquieren los conocimientos básicos, habilidades (de codificación y oral) y actitudes que se requieren para leer y escribir (Storch & Loningan, 2002; Whitehurst & Lonigan, 1998). A través de la pre-numeracidad, los niños desarrollan las habilidades preparatorias para el logro matemático: conteo, relaciones numéricas y operaciones aritméticas (Purpura, Hume, Sims & Lonigan, 2011; Raghubar & Barnes, 2017).

E

Habilidades motrices: tradicionalmente se hace una distinción de habilidades motrices gruesas y finas. Las habilidades motrices gruesas implican el uso de músculos grandes y comprenden el equilibrio, la orientación y el movimiento del tronco y las extremidades. Las habilidades motrices finas implican la coordinación de músculos pequeños para lograr movimientos precisos y de integración (Cameron, Cottone, Murrah, & Grissmer, 2016; Van der Fels et al., 2015).

Funciones ejecutivas: procesos cognitivos de alto orden que asisten al control de pensamiento y acción (Carlson, 2005). En los niños pequeños, hay dos subdominios básicos distinguibles pero interrelacionados: control inhibitorio y memoria de trabajo (Lerner & Lonigan, 2014; Miller et al., 2012; Karalunas, Bierman y Huang-Pollock, 2016). El control inhibitorio se refiere a la capacidad de suprimir las respuestas predominantes para dar una respuesta alternativa; la memoria de trabajo se refiere a la capacidad de controlar, retener y actualizar información mental (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Se ha hecho una distinción adicional entre funciones ejecutivas calientes y frías. Las funciones ejecutivas calientes implican un procesamiento afectivo y motivacional y exigen evaluaciones constantes de la importancia afectiva de los estímulos; mientras que las funciones ejecutivas frías son evocadas por problemas abstractos y descontextualizados (Zelazo & Müller, 2002).

Competencia socioemocional: conjunto de habilidades sociales y emocionales que están inextricablemente interrelacionadas. Estas habilidades incluyen, por ejemplo, la capacidad de desarrollar relaciones positivas con los demás y actuar de manera prosocial; y la capacidad de identificar, regular y expresar emociones de una manera cultural y socialmente apropiada (Campbell et al., 2016; Camras, Shuster, & Fraumeni, 2014).

El objetivo general del Estudio del Desarrollo Integral del Preescolar (EDIP) fue explorar el desarrollo y relaciones entre múltiples dominios del desarrollo en niños mexicanos de 3 a 6 años de edad. Conscientes del desarrollo acelerado y no lineal de los niños pequeños, se exploró la estabilidad y la equivalencia de la estructura factorial de los dominios clave en varios momentos de desarrollo (Capítulo 2). Además, para expandir una visión holística del desarrollo infantil, en este proyecto, se colocaron a las funciones ejecutivas en un papel central y se tomaron como el ancla que conecta e influye diferentes dominios del desarrollo: por un lado, actuando como mediador en la relación entre las habilidades motrices y habilidades pre-académicas (Capítulo 3) y, por otro lado, teniendo una relación bidireccional con la competencia socioemocional (Capítulo 4).

Capítulo 2: Invarianza de medición en la primera infancia

Este estudio se dedicó a explorar la estabilidad y la equivalencia de los constructos latentes que representan las habilidades pre-académicas, funciones ejecutivas y habilidades motrices. Además de dilucidar la tensión existente entre la necesidad metodológica de tener construcciones invariantes y la naturaleza cambiante inherente de este momento de desarrollo. Primero, se exploró la estructura factorial de cada dominio con base en las estructuras usualmente propuestas en la literatura de la primera infancia. Además, se exploró si la misma estructura se mantenía estable en un diseño transversal y uno longitudinal. El diseño transversal incluyó los tres grados de educación preescolar en México: preescolar 1 (ECE 1; de 3 a 4 años), preescolar 2 (ECE 2; de 4 a 5 años) y preescolar 3 (ECE 3; de 5 a 6 años). El diseño longitudinal incluyó dos evaluaciones realizadas en cada año escolar—a mediados y finales—para un total de seis tiempos de evaluación. Se econtró que, en general, una estructura de factor único era la mejor manera de representar las habilidades pre-académicas y las funciones ejecutivas. Para las habilidades motrices, se seleccionó un modelo de dos factores considerando habilidades motrices finas y gruesas. Además, se probaron tres niveles de invariancia de la medición: configuracional (el constructo presenta una estructura factorial equivalente), métrica (los indicadores aportan cargas equivalentes) y escalar (tienen medias equivalentes). Ninguno de los dominios logró una invariancia de configuración completa. Sin embargo, se logró invariancia de configuración parcial después de reducir el rango de desarrollo: para habilidades pre-académicas al incluir solo los últimos grados de educación preescolar (ECE2 y ECE3) y al excluir el primer tiempo de evaluación; para funciones ejecutivas al incluir solo los últimos grados de educación preescolar o solo los tiempos de evaluación 3 y 5; para habilidades motrices al incluir sólo los primeros cuatro tiempos de evaluación. La invariancia métrica se logró parcialmente para las funciones ejecutivas en el diseño transversal y para las habilidades pre-académicas y las habilidades motrices en el diseño longitudinal. Ninguno de los dominios logró invariancia escalar. Finalmente, en este estudio se argumenta que lograr al menos invariancia configuracional puede ser un compromiso razonable entre el rigor de las metodologías estadísticas y la naturaleza cambiante del desarrollo de los niños pequeños. Basados en la idea que el tener la misma estructura de factores en los diferentes puntos de evaluación (o grado escolar) permite que las construcciones latentes se puedan modelar juntas; mientras que la falta de otros niveles de invariancia captura por su lado las diferencias de desarrollo del constructo.

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Capítulo 3: El desarrollo motriz-cognitivo de los niños pequeños.

Aunque teóricamente las funciones ejecutivas se han colocado como un punto central en la relación entre las habilidades motrices y las habilidades pre-académicas, se necesita una mayor exploración empírica para aclarar el posible papel mediador de las funciones ejecutivas en esta relación en niños pequeños. Por lo tanto, en este capítulo, se probó un modelo de mediación de funciones ejecutivas en la relación entre las habilidades motrices y las habilidades pre-académicas en dos cohortes separadas, una cohorte de niños “pequeños”, que incluye niños de 3.5 a 5 años, y una cohorte de niños “grandes”, que incluye niños de 4.5 a 6 años. Para ambos grupos, se encontró una relación fuerte, significativa, y positiva entre las habilidades motrices y las funciones ejecutivas, y entre las funciones ejecutivas y las habilidades pre-académicas. Con respecto al efecto de mediación, se encontró que, en el grupo más pequeño, la relación entre las habilidades motrices y las habilidades pre-académicas solo está presente a través de una mediación completa de las funciones ejecutivas, incluso después de controlar por rendimiento y relaciones iniciales. En el grupo de más edad, el efecto de mediación total de las funciones ejecutivas sobre la relación entre las habilidades motrices y las habilidades pre-académicas se desvaneció al incluir el rendimiento y relaciones iniciales. De acuerdo con lo propuesto por Davids y colegas (2011) estos resultados respaldan que la relación motriz-cognitiva parece depender de la edad, ya que las diferentes habilidades involucradas pueden desarrollarse a diferentes velocidades y, por lo tanto, influir en la forma en que se expresan las relaciones.

Capítulo 4: Competencia socioemocional y funciones ejecutivas

Este capítulo satisfizo un doble interés. El primero fue capturar el desarrollo de la competencia socioemocional en niños preescolares. Para tal fin, se adoptó un enfoque centrado en la persona, por medio del análisis de clases latentes, para capturar las combinaciones típicas de las respuestas emocionales y conductuales de los niños a situaciones socialmente desafiantes. Un segundo interés fue analizar la relación entre la competencia socioemocional y los componentes calientes y fríos de las funciones ejecutivas. Se propuso que esta relación es potencialmente bidireccional, en oposición a la frecuentemente asumida relación unidireccional. Se identificaron diferentes perfiles de competencia socioemocional: a los 3.5 años se identificaron cuatro perfiles que diferían principalmente en sus respuestas emocionales; a los 4.5 años se identificaron cinco perfiles, aunque los perfiles a esta edad también diferían principalmente en las respuestas emocionales, las respuestas conductuales comenzaron a desempeñar un papel en la diferenciación de los perfiles; finalmente, a los 5.5 años se identificaron cuatro perfiles, que se diferenciaron más claramente en su combinación de respuestas tanto emocionales como conductuales. Basados en estos perfiles, se probó la bidireccionalidad de la competencia socioemocional con funciones ejecutivas calientes y frías. No se encontró evidencia de una relación significativa entre la competencia socioemocional y las funciones ejecutivas calientes. La bidireccionalidad propuesta fue atestiguada solo con funciones ejecutivas frías y en una etapa de desarrollo posterior (de 4.5 a 5.5 años), pero no en una etapa anterior (de 3.5 a 4.5 años). El desempeño en funciones ejecutivas frías (control inhibitorio) a los 4.5 años se relacionó con los perfiles de competencia socioemocional de los niños un año después. Por ejemplo, los niños con un alto desempeño en control inhibitorio presentaron una menor probabilidad de pertenecer al perfil "Enojado-triste & Agresivo” en comparación con los de bajo rendimiento. También se observó una relación significativa entre la membresía a un perfil de competencia socioemocional a los 4.5 años de edad y el desempeño de los niños en funciones ejecutivas frías a los 5.5 años. Por ejemplo, los niños de 4.5 años en el perfil “Principalmente feliz"—un signo de reconocimiento emocional inmaduro—tuvieron la mayor probabilidad de tener un bajo rendimiento en funciones ejecutivas frías a los 5.5 años. Finalmente, estos hallazgos acentúan el papel del reconocimiento emocional en el desarrollo de las funciones ejecutivas, particularmente el control inhibitorio, y proporcionan evidencia empírica que respalda a los modelos teóricos que proponen una relación bidireccional entre la competencia socioemocional y las funciones ejecutivas.

Observaciones finales

Esta investigación contribuye a aclarar cómo se desarrollan y cómo se relacionan los dominios clave del desarrollo en el período de la primera infancia de los niños mexicanos. La estrecha interrelación del desarrollo presente en los primeros años de la infancia, particularmente con las funciones ejecutivas, se puede utilizar para crear y facilitar una sinergia del desarrollo. Por un lado, dominios como las habilidades motrices o la competencia socioemocional funcionan como una influencia importante en el desarrollo de las funciones ejecutivas. Por otro lado, las funciones ejecutivas ayudan al desarrollo de la competencia socioemocional y las habilidades pre-académicas. Una mayor comprensión de cómo se desarrollan las funciones ejecutivas en niños en desventaja socioeconómica, y sus interconexiones con otros dominios del desarrollo—explorando cuándo y cómo se presentan—podría ayudar a canalizar mejor las estrategias para impulsar un desarrollo integral.

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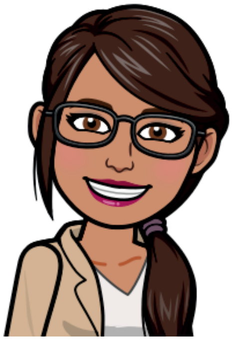

Fabiola Figueroa Esquivel was born on the 17th of January of 1987 in Mexico City, Mexico. She studied Psychology at the Universidad del Pedregal in Mexico City, where she graduated with honors. During her studies, she did an internship at the admission department of the University as assistant psychologist, and collaborated in the admission procedures and as career counselor.

Next to her studies, she joined the laboratory of Neuropsychology in the Faculty of Psychology from the Universidad Nacional Autónoma de México (UNAM) as research assistant. Here she participated in research projects related to the development and stimulation of executive functions in young children. Afterward, she worked at the National Assessment Center for Higher Education (CENEVAL) where she supported the development and validation of tests.

In 2013, she enrolled in the International Master of Education at the University of Groningen, the Netherlands. She graduated in 2014, and received the prize for best Master thesis of the department of Educational Sciences, Pedagogy and Special Needs Education (*Scriptieprijs 2014*). In 2015, together with her supervisory team, Fabiola developed a research proposal and obtained a grant from the Mexican government (CONACYT) to continue with her doctoral studies at the Groningen Institute for Educational Research (GION), at the University of Groningen. During her doctoral studies, she specialized on several statistical techniques, particularly structural equation modelling. . She has participated as reviewer for a peer-reviewed scientific journal, and she has presented her research in diverse national and international conferences. Fabiola also performed teaching tasks in a research methods course at the Master's level.

A

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